Volume 28 JANUARY, 1944 Number 1

BULLETIN
of the
American Association *of* Petroleum Geologists

CONTENTS

Stratigraphy of Northeastern Anzoátegui, Venezuela *By Hollis D. Hedberg and Augustin Pyre* 1

General Geology of Mississippi *By Tom McGlothlin* 29

Petrology of Bethel Sandstone of South-Central Illinois *By Willard D. Pye* 63

GEOLOGICAL NOTES

Algal Reefs in Cretaceous Austin Chalk of Terlingua District, Brewster County, Texas *By J. Harlan Johnson* 123

Acetone for Determining Oil Content of Well Cuttings *By Leland W. Jones* 124

Carmi Pool, Pratt County, Kansas *By John E. Galley* 125

REVIEWS AND NEW PUBLICATIONS

Oil and Gas Field Development in United States. Year Book 1943, by National Oil Scouts and Landmen's Association *By W. A. Ver Wiebe* 127

Rock Colors *By Ronald K. DeFord* 128

Recent Publications 137

THE ASSOCIATION ROUND TABLE

Membership Applications Approved for Publication 139

Association Committees 140

Members in Military and Government Service *By F. L. Aurin* 142

Code of Ethics 164

Joint Annual Meeting, Dallas, March 21-23, 1944 *By A. Rodger Denison* 166

Japanese Journals Needed 168

AT HOME AND ABROAD

Current News and Personal Items of the Profession 169

COPYRIGHT, 1944, BY THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

S S C offers to the petroleum industry throughout the world, the experience gained in more than 132 crew years of Seismic Exploration, Radioactivity Logging, and Well Logging by the Hayward method.

S S C will continue to maintain a permanent administrative and interpretational staff, field crews, equipment, laboratories, and warehouses to service its clients in South America.

As rapidly as conditions will permit the facilities of S S C will again be available on a World Wide basis.

Seismograph Service Corporation

CONSULTING EXPLORATION GEOPHYSICISTS

Caracas, Venezuela

KENNEDY BUILDING

TULSA, OKLAHOMA, U. S. A.

Barranquilla, Colombia

BULLETIN

of the

AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OFFICE OF PUBLICATION, 708 WRIGHT BUILDING, TULSA, OKLAHOMA

CAREY CRONEIS, *Editor*

WALKER MUSEUM, UNIVERSITY OF CHICAGO, CHICAGO 37, ILLINOIS

ASSOCIATE EDITORS

GENERAL	K. C. HEALD, Gulf Oil Corporation, Box 1166, Pittsburgh 30, Pa. HUGH D. MISER, U. S. Geological Survey, Washington 25, D. C. THERON WASSON, Pure Oil Company, 35 E. Wacker Drive, Chicago 1, Ill.
APPALACHIANS	
North	JOHN R. REEVES, Penn-York Natural Gas Corporation, Buffalo, N. Y.
NORTH CENTRAL STATES	R. B. NEWCOMBE, 2029 South St. Johns Ave., Highland Park, Ill.
KANSAS	ANTHONY FOLGER, 238 Ridgewood Drive, Wichita 2, Kan.
OKLAHOMA	
Western	ROBERT H. DOTT, Oklahoma Geological Survey, Norman, Okla.
Eastern	SHERWOOD BUCKSTAFF, Shell Oil Company, Inc., Box 1191, Tulsa 2, Okla.
TEXAS	
North and Central	J. B. LOVEJOY, Gulf Oil Corporation, Fort Worth 1, Tex.
Northeastern	C. I. ALEXANDER, Magnolia Petroleum Company, Tyler, Tex.
San Antonio	JOHN R. SANDIDGE, Magnolia Petroleum Company, San Antonio 5, Tex.
Permian Basin	E. RUSSELL LLOYD, Box 1026, Midland, Tex.
GULF COAST	SIDNEY A. JUDSON, Texas Gulf Producing Company, Houston 1, Tex. MARCUS A. HANNA, Gulf Oil Corporation, Houston 1, Tex.
ARKANSAS AND NORTH LOUISIANA	ROY T. HAZZARD, Gulf Refining Company of Louisiana, Shreveport, La.
ROCKY MOUNTAINS	A. E. BRAINERD, Continental Oil Company, Denver 2, Colo.
CALIFORNIA	W. S. W. KEW, Standard Oil Company, Los Angeles 54, Calif. W. D. KLEINPELL, Box 1131, Bakersfield, Calif.
FOREIGN	
Canada	THEODORE A. LINK, Imperial Oil, Ltd., Calgary, Alberta
South America	HOLLIS D. HEDBERG, Mene Grande Oil Co., Apt. 45, Barcelona, Venezuela

THE BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS is published by the Association on the 15th of each month. Editorial and publication office, 708 Wright Building, Tulsa, Oklahoma, Post Office Box 979.

THE SUBSCRIPTION PRICE to non-members of the Association is $15.00 per year (separate numbers, $1.50) prepaid to addresses in the United States. For addresses outside the United States, an additional charge of $0.40 is made on each subscription to cover extra wrapping and handling.

British agent: Thomas Murby & Co., 40 Museum Street, London, W. C. I.

CLAIMS FOR NON-RECEIPT of preceding numbers of THE BULLETIN must be sent Association headquarters within three months of the date of publication in order to be filled gratis.

BACK NUMBERS OF THE BULLETIN, as available, can be ordered from Association headquarters. Cloth-bound Vols. 11 (1927) to 15 (1931), $6.00; Vols. 22 (1938) to 24 (1940); Vols. 26 (1942), to 27 (1943), each $17.00. Separate numbers, and a few nearly complete sets are available. Descriptive price list sent on request. Special prices to members and associates. Discounts to libraries. *Geology of Natural Gas* (1935), $6.00 ($4.50 to members and associates). *Geology of Tampico Region, Mexico* (1936), $4.50 ($3.50 to members and associates). *Gulf Coast Oil Fields* (1936), $4.00 ($3.00 to members and associates). *Miocene Stratigraphy of California* (1938), $5.00 ($4.50 to members and associates). *Stratigraphic Type Oil Fields* (1941), $5.50 ($4.50 to members and associates). *Source Beds of Petroleum* (1942), $4.50 ($3.50 to members and associates). *Permian of West Texas and Southeastern New Mexico* (1942), $2.00 ($1.50 to members and associates). *Petroleum Discovery Methods* (1942), $1.00.

THE BULLETIN gives senior authors 35 reprints of major papers. Additional reprints, in limited numbers, and for private distribution, are furnished at cost, if orders accompany corrected galley proof.

Association Headquarters—708 Wright Building, 115 and 117 West Third Street, Tulsa, Oklahoma.

Communications about the Bulletin, manuscripts, editorial matters, subscriptions, special rates to public and university libraries, publications, membership, change of address, advertising rates, and other Association business should be addressed to

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

BOX 979

TULSA, 1, OKLAHOMA

Entered as second-class matter at the Post Office at Tulsa, Oklahoma, and at the Post Office at Menasha, Wisconsin, under the Act of March 3, 1879. Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized March 9, 1923.

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS, INC.

Organized at Tulsa, Oklahoma, February 10, 1917, as the Southwestern Association of Petroleum Geologists. Present name adopted, February 16, 1918. Incorporated in Colorado, April 23, 1924. Domesticated in Oklahoma, February 9, 1925.

OFFICERS FOR THE YEAR ENDING MARCH, 1944

A. RODGER DENISON, *President*, Tulsa, Oklahoma
ROBERT E. RETTGER, *Secretary-Treasurer*, Dallas, Texas
ROBERT W. CLARK, *Vice-President*, Los Angeles, California
CAREY CRONEIS, *Editor*, Chicago, Illinois

The foregoing officers, together with the *Past-President*, FRITZ L. AURIN, Fort Worth, Texas, constitute the Executive Committee.

DISTRICT REPRESENTATIVES

(Representatives' terms expire immediately after annual meetings of the years shown in parentheses)

Amarillo: Elisha A. Paschal (46), Amarillo, Tex
Appalachian: M. Gordon Gulley (45), Pittsburgh, Pa.
Canada: J. G. Spratt (45), Calgary, Canada
Capital: L. W. Stephenson (44), Washington, D. C.
Dallas: Dilworth S. Hager (44), Dallas, Tex.
East Oklahoma: T. C. Hiestand (44), Bartlesville,
R. Clare Coffin (45), Lucian H. Walker (45), Tulsa
Fort Worth: Charles E. Yager (45), Fort Worth, Tex.
Great Lakes: Edwin G. Cole (45), Evansville, Ind.; Darsie A. Green (45), Olney, Ill.
Houston: R. C. Bowles (44), Leslie Bowling (44),
S. G. Gray (45), W. B. Moore (45), Houston, Tex.
Michigan: Rex P. Grant (45), Lansing, Mich.
New Mexico: Hugh A. Tanner (45), Hobbs, N. Mex.
New York: Lewis G. Weeks (45), New York City
Pacific Coast: Karl Arleth (44), Max L. Krueger (44), Los Angeles, Calif.
Mason L. Hill (45), James C. Kimble (45), Bakersfield, Calif.
Rocky Mountains: Charles S. Lavington (45), Denver, Colo.
Shreveport: J. D. Aimer (45), Shreveport, La.
South America: Philip E. Nolan (45), Caracas, Venezuela
Southeast Gulf: Tom McGlothlin (45), Jackson, Miss.
Southern Louisiana: Gordon I. Atwater (45), New Orleans
So. Permian Basin: Oscar R. Champion (45), Midland, Tex.
South Texas: Robert N. Kolm (44), San Antonio
Tyler: T. C. Cash (45), Tyler, Tex.
West Oklahoma: R. W. Camp (45), Oklahoma City, Okla.
Wichita: W. C. Imbt (45), Wichita, Kan.
Wichita Falls: W. C. Bean (44), Wichita Falls, Tex.

DIVISION REPRESENTATIVES

Paleontology and Mineralogy

J. Harlan Johnson (44), Golden, Colorado
Henryk B. Stenzel (44), Austin, Texas

PACIFIC SECTION (Chartered, March, 1925)

R. G. REESE, *President*, Standard Oil Company of California, Standard Oil Building, Los Angeles, California
GLENN H. BOWES, *Vice-President*, Continental Oil Company, 601 W. 5th Street, Los Angeles, California
ROBERT T. WHITE, *Secretary-Treasurer*, Barnsdall Oil Company, Petroleum Building, Los Angeles, California
Membership restricted to members of the Association in good standing, residing in Pacific Coast states. Dues: $1.50 per year

SOUTH TEXAS SECTION (Chartered, April, 1929)

WILLIAM H. SPICE, JR., *President*, 2101 Alamo National Building, San Antonio, Texas
ARTHUR H. PETSCH, *Secretary-Treasurer*, 1417 Milam Building, San Antonio, Texas
Membership limited to persons eligible to Association membership. Dues: $2.50. Annual meeting in October.

DIVISION OF PALEONTOLOGY AND MINERALOGY
SOCIETY OF ECONOMIC PALEONTOLOGISTS AND MINERALOGISTS

(Organized, March, 1927; affiliated, March, 1928; chartered, technical division, April, 1930)
J. HARLAN JOHNSON, *President*, Colorado School of Mines, Golden, Colorado
HENRYK B. STENZEL, *Secretary-Treasurer*, Bureau of Economic Geology, Austin, 12, Texas

SEND DUES, SUBSCRIPTIONS AND ORDERS FOR BACK NUMBERS TO BOX 979, TULSA, 1, OKLAHOMA. The Society and the Paleontological Society jointly issue six times a year the *Journal of Paleontology*, J. Marvin Weller, Illinois Geological Survey, Urbana, Illinois, and C. Wythe Cooke, U. S. National Museum, Washington, D. C., editors: subscription, $6.00. The *Journal of Sedimentary Petrology*, W. H. Twenhofel, editor, University of Wisconsin, Madison, Wisconsin, is issued three times a year: subscription, $3.00. Single copies, *Journal of Paleontology*, $2.00; *Journal of Sedimentary Petrology*. $1.50. Society dues: with *Jour. Pal.*, $5.00; with *Jour. Sed. Petrology*, $3.00; with both, $8.00 per year.

AFFILIATED SOCIETIES

(Dates of affiliation in parentheses)

Alberta Society of Petroleum Geologists, Calgary, Alberta, Canada (31). J. D. Weir, Secy., Dominion Oil Company, Ltd.
Appalachian Geological Society, Charleston, W. Virginia (31). Cramon Stanton, Secy., United Carbon Company, Box 1913
Ardmore Geological Society, Ardmore, Oklahoma (36). J. M. Westheimer, Secy., Samedan Oil Corporation, Box 959
Corpus Christi Geological Society, Corpus Christi, Texas (43). John Bruce Scrafford, Secy., Driscoll Building
Dallas Petroleum Geologists, Dallas, Texas (35). H. C. Vanderpool, Secy., Seaboard Oil Company, Continental Bldg.
East Texas Geological Society, Tyler, Texas (32). Lynn L. Harden, Secy., Sinclair Prairie Oil Co., Box 1100, Tyler
Fort Worth Geological Society, Fort Worth, Texas (31). Richard H. Schweers, Secy., The Texas Company, Box 1720
Houston Geological Society, Houston, Texas (32). W. B. Moore, Secy., Atlantic Refining Company, Box 1346
Illinois Geological Society (39). Fred H. Moore, Secy., Magnolia Petroleum Corporation., Box 535, Mt. Vernon
Indiana-Kentucky Geological Society (38). Hillard W. Bodkin, Superior Oil Co., Evansville, Ind.
Kansas Geological Society, Wichita, Kansas (31). Delbert J. Costa, Secy, Superior Oil Co. of California, 417 First Natl. Bank
Michigan Geological Society (37). Mrs. Lucille Esch, Secy., State Geological Survey, Lansing
Mississippi Geological Society, Jackson, Miss. (41). C. L. Morgan., Secy., Consulting, Edwards Hotel
New Orleans Geological Society, New Orleans, La. (43). B. E. Bremer, Secy., The Texas Company, Box 252
North Texas Geological Society, Wichita Falls, Texas (38). C. M. Ferguson, Secy., Magnolia Petrol. Co., 500 Waggoner Bldg.
Oklahoma City Geological Society, Oklahoma City, Okla. (31). Theodore G. Glass, Secy., Sinclair Prairie Oil Co., Colcord Bldg.
Panhandle Geological Society, Amarillo, Texas (32). Cary R. Wagner, Jr., Secy., Pure Oil Co., Box 2127
Shawnee Geological Society, Shawnee, Oklahoma (31). Marcelle Mousley, Secy., Atlantic Refining Company
Shreveport Geological Society, Shreveport, Louisiana (32). E. P. Ogier, Secy., c/o W. C. Spooner, Box 1195
Society of Exploration Geophysicists, Houston, Tex. (32). Hart Brown, Secy., Brown Geophysical Company, Box 6005
South Louisiana Geological Society, Lake Charles, La. (37). A. L. Morrow, Secy., Magnolia Petroleum Company
Tulsa Geological Society, Tulsa, Oklahoma (31). James A. Price, Secy., W. C. McBride, Inc., 625 Wright Building
West Texas Geological Society, Midland, Texas (38). Dana M. Secor, Secy., Atlantic Refining Company

There are a good many reasons why critical geophysicists prefer

HALOID RECORD

SEISMOGRAPH RECORDING PAPER

. . . and popular among these reasons are the facts that Haloid Record is plenty tough, resists heat, withstands humidity and always provides sharp lines and legible contrast.

Even under the most adverse conditions, in the field or in the laboratory, you can depend on Haloid Record to give you consistently high performance. Superior geophysical recordings are yours because Haloid Record successfully combines the advantages of photographic excellence and resistance to abuse.

THE HALOID CO., 601 Haloid St., Rochester 3, N.Y.

★ ***BUY MORE WAR BONDS*** ★

HAVE YOU SEEN SULLIVAN'S $50,000 CHUCK?

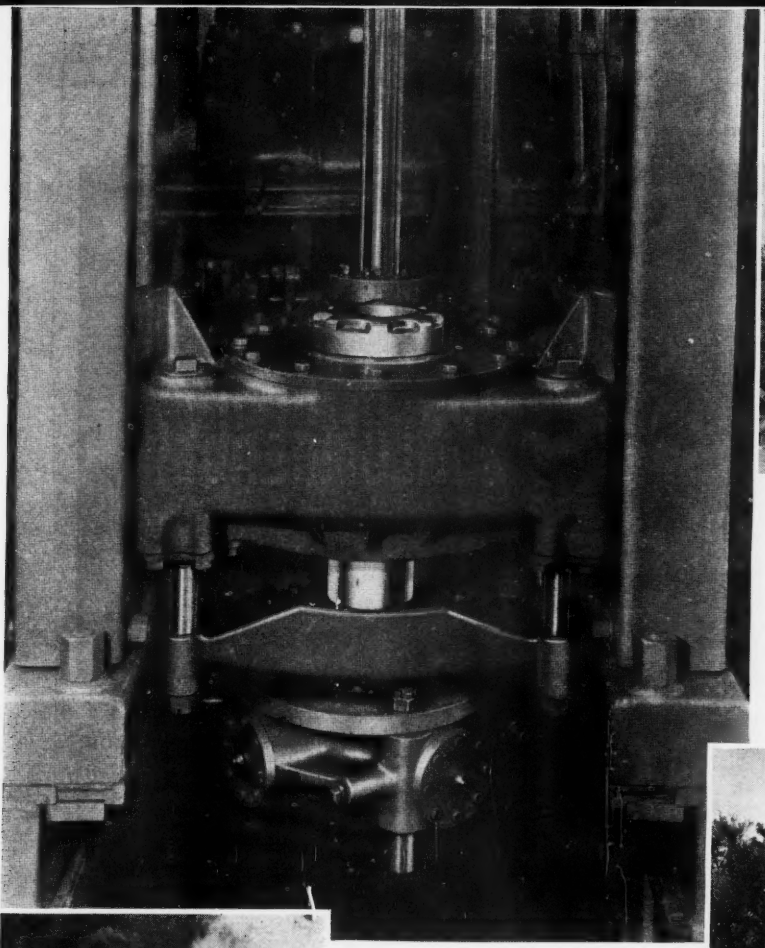
The automatic chuck, which is but one of a number of features that set Sullivan Core Drills apart from any other rig on the market, eliminates hand set screws and saves the time required to loosen and tighten them. 30 seconds per rod change is an average savings for this automatic chuck, which at a drilling speed of one foot per minute means 200 feet of hole more per day. At 25¢ a foot, the saving is equal to the return on an investment capitalized at $50,000.

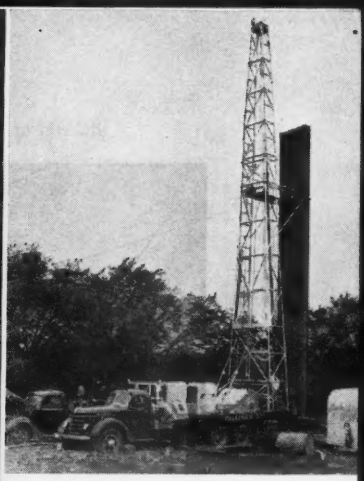
There are other outstanding features in the Sullivan line... the hydraulic device for retracting the drilling table back from the hole; a built-in hydraulic feed mechanism; hydraulic plungers for make-up and break-out tongs and spinning line and hydraulic cylinders for raising and lowering the mast. Each feature means more time saved, either between locations or in changing rods, greater safety for operators and equipment, and important reductions in costs. They are *plus* features exclusive with Sullivan, available nowhere else, crucial in any operation. Write for more information today. SULLIVAN MACHINERY CO., Michigan City, Indiana. *In Canada:* Canadian Sullivan Machinery Co., Ltd., Dundas, Ontario.

ARMY E NAVY

Sullivan OFFICES

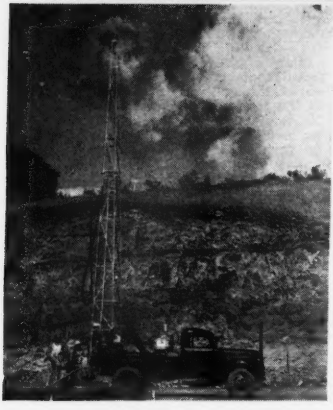
Chicago, Dallas, Denver, El Paso, Los Angeles, Mexico City, New York and Tulsa. Branches in many other principal cities throughout the world.





MODEL 300 . . Up to 3500 feet.
A heavy-weight, portable drilling rig for slim-hole production drilling. A younger brother to the large oil field rotaries; arranged for truck mounting to speed up moves between drilling locations. Operates same as conventional rotary plus added features which include hydraulic and make and break tongs. Capacity 40,000 lb. drilling string.

MODEL 200 . . . Up to 2000 feet
A medium weight portable drilling rig for deep structure testing or shallow slim-hole production drilling. Equipped with hydraulic feeding mechanism including automatic hydraulic chuck. Kelly drive—optional. Also available with rotary table for shallow slim-hole production drilling. Capacity 20,000 lb. drilling string.



MODEL 37 . . . Up to 1200 feet
A light portable drilling rig for shot-hole drilling, shallow structure testing, and blast hole work. Equipped with hydraulic feeding mechanism for core testing and changeable to kelly drive for shot-hole drilling. Capacity 1200 ft. of 2″ core or 850 feet of 6″ hole.

***Sullivan* PRODUCTS**

Include Air Compressors, Hoists both Air and Electric, Rock Drills, Motorized Core Drills and Stringalite Portable Safety Lighting Cable for Derricks.

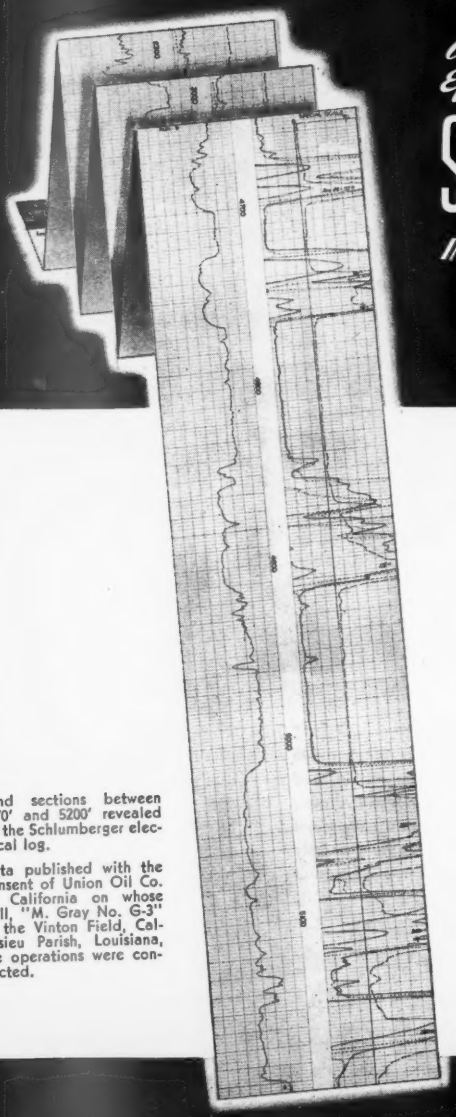
SULLIVAN

A COMPLETE LINE OF OILFIELD EQUIPMENT

Case History Demonstrates the Efficiency and Economy of

SCHLUMBERGER

INTEGRATED WELL SERVICES



Sand sections between 4670' and 5200' revealed by the Schlumberger electrical log.

Data published with the consent of Union Oil Co. of California on whose well, "M. Gray No. G-3" in the Vinton Field, Calcasieu Parish, Louisiana, the operations were conducted.

Here is an example of how oil operators may obtain

MAXIMUM SUBSURFACE DATA AT MINIMUM COST AND LOSS OF RIG TIME

1. **MAXIMUM SUBSURFACE DATA:** The following Schlumberger services were used on this well:
   - **A. Electrical Logging**—Three surveys at 656'-4436', 4436'-4790', and 4790'-5359' respectively. Although no conventional cores were taken, these surveys provided:
     1. Correlation. 2. Discovery of oil sands. 3. Water levels.
   - **B. Side Wall Coring**—Fifty-one side wall cores were taken in three operations subsequent to three electrical logging surveys. These cores:
     1. Confirmed the existence of oil sands and their nature
     2. Indicated the extent of saturation
     3. Determined gas-oil contact
   - **C. Photoclinometer**—Since this well was on the flank of the dome and the sands dipped steeply, it was important to know the exact location of the bottom of the hole. A Photoclinometer survey was made in connection with the second logging and sampling operation.
   - **D. Dipmeter**—In order to ascertain the true thickness of the sand and to aid in making subsequent locations, a Dipmeter survey was made after the third electrical logging survey to determine the magnitude and direction of dip.
   - **E. Precision Gun Perforating**—For precise shooting, the same truck and cable used for the above operations were also used for the gun perforating.
2. **MINIMUM COST AND LOSS OF RIG TIME:** This wealth of information was obtained at a total cost of approximately $2,200.00. Because of the integrated nature of the various services, only four trips to the well location with a single service unit were required. Due also to this unique feature of Schlumberger service, total rig time required for all operations was only 21 hours.

SCHLUMBERGER WELL SURVEYING CORPORATION

HOUSTON, TEXAS

Bulletin Advertisers

Atlas Powder Company xxxi

Baker Oil Tools, Inc. xxix
Baroid Sales Division xxxiv
Barret, William M., Inc. .....
Bausch and Lomb xvii

Dowell Incorporated .....

Eastman Oil Well Surveys .....
Economic Geology Publishing Company .. xxiv

Federal Electric Company xxvi
First Natl. Bank and Trust Co. of Tulsa .. xviii

General Geophysical Company xxi
Geophysical Service, Inc. ..... Cover iii
Geotechnical Corporation xviii
Gulf Publishing Company xx

Haloid Company iii
Hercules Powder Company, Inc. .....
Hughes Tool Company, Inc. ..... Cover iv

Independent Exploration Company xxxv

Journal of Geology xxiv
Journal of Paleontology .....
Journal of Sedimentary Petrology .....

Lane-Wells Company xxv
Lufkin Rule Company .....

National Geophysical Company xxvii

Reed Roller Bit Company xxxvi
Robert H. Ray, Inc. .....
Rogers-Ray Incorporated .....

Schlumberger Well Surveying Corporation .. vi
Seismic Explorations, Inc. xxiii
Seismograph Service Corporation ..... Cover ii
Society of Exploration Geophysicists .....
Spencer-Lens Company .....
Sperry-Sun Well Surveying Company .....
Sullivan Machinery Company ..... iv-v

Thompson Tool Company, Inc. xxii
Triangle Blue Print and Supply Company .. xxiv

United Geophysical Company viii

Western Geophysical Company xix

PROFESSIONAL CARDS

California ix
Colorado ix
Illinois x
Louisiana x
New York x
Ohio x
Oklahoma xi
Pennsylvania xi
Texas ..... xi, xii, xiii
West Virginia xiii
Wyoming xiii

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

Appalachian xvi
Ardmore xv
Corpus Christi xv
Dallas xv
East Texas xvi
Exploration Geophysicists .xvi
Fort Worth xvi
Houston xvi
Illinois xiv
Indiana-Kentucky xiv
Kansas xiv
Michigan xiv
Mississippi xv
New Orleans xiv
North Texas xvi
Oklahoma City xv
Rocky Mountain xiv
Shawnee xv
Shreveport xiv
South Louisiana xiv
South Texas xvi
Tulsa xv
West Texas xvi

Articles for February *Bulletin*

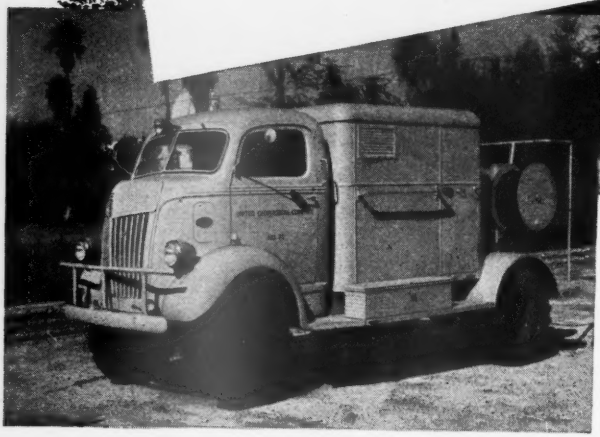
Porter Oil Field, Midland County, Michigan
By KENNETH K. LANDES

West Ranch Oil Field, Jackson County, Texas
By A. J. BAUERNSCHMIDT

Geologic Factors in Unitized Pressure Maintenance, Jones Sand Reservoir, Schuler Field, Arkansas
By GEORGE R. ELLIOTT

Well Spacing—Its Effect on Recoveries and Profits
By STUART K. CLARK, C. W. TOMLINSON, and J. S. ROYDS

BETTER SERVICE
when
IT'S NEEDED MOST!



Out of Gas?

Will the U.S. run out of oil in a few years?

Yes, said Navy Secretary Frank Knox last week before the House Naval Affairs Committee. He predicted a serious shortage of crude oil within a year. Within 14 years the U.S. will be a "have-not" nation in oil, he said, when the last drop of its oil fields is drained (if the present rate continues). Same day, Assistant Deputy Petroleum Administrator Robert E. Allen warned that the U.S. is threatened with a permanent oil shortage in two years unless "miraculously prompt" discovery of new fields offsets declining production. The U.S. must bring in 20,000 new wells a year, said he, to maintain present production.

FROM
TIME MAGAZINE

United has enlarged its service program to meet the expanding needs of the oil industry.

Due to the approaching critical oil shortage the petroleum industry must make every effort to discover new resources. And by enlarging facilities and serving more and more territory, UNITED is assisting materially in today's accelerated exploration programs.

UNITED'S modern equipment . . . advanced computing technique . . . trained personnel . . . and continuous research assure operators of complete and extremely accurate surveys.

UNITED'S dependable, proven geophysical service is based on experience under all types of field conditions.

UNITED GEOPHYSICAL COMPANY

MAIN OFFICE: **595 EAST COLORADO STREET, PASADENA 1, CALIFORNIA**

805 THOMPSON BLDG., TULSA 3, OKLA. • RUA URUGUIANA 118, RIO DE JANEIRO, BRAZIL
CASILLA 1162, SANTIAGO, CHILE

Volume 28 Number 1

BULLETIN
of the
AMERICAN ASSOCIATION OF
PETROLEUM GEOLOGISTS

JANUARY, 1944

STRATIGRAPHY OF NORTHEASTERN ANZOÁTEGUI, VENEZUELA[1]

HOLLIS D. HEDBERG[2] AND AUGUSTIN PYRE[2]
Barcelona, Venezuela

ABSTRACT

A reference section for the 40,000 feet of Cretaceous and Tertiary sediments of northeastern Anzoátegui (Venezuela) was established several years ago on Rio Querecual and in the vicinity of the town of Santa Inés. Subsequent studies on the west and east have given a more complete three-dimensional picture of the original formations and their facies changes and have filled those parts of the stratigraphic section poorly represented on Rio Querecual. During the course of this work numerous fossil collections have been made and these have been submitted to specialists for study with the result that more authoritative data on the ages of the several formations are now available.

The oldest rocks of northeastern Venezuela are the schists, phyllites, quartzites, and metamorphosed limestones of the Caribbean series, probably early Mesozoic in age. These rocks are in fault contact with unmetamorphosed Lower Cretaceous sediments which are well represented in northeastern Anzoátegui and include about 5,000 feet of laterally variable shallow-water sandstones, shales, and reef limestones belonging to the Barranquín, El Cantil, and Chimana formations. These are followed by a deeper-water facies of 3,000–4,000 feet of black carbonaceous-bituminous limestone and calcareous shale with local sandstone and chert developments in its upper part, constituting the Guayuta group (Querecual and San Antonio formations) of Upper Cretaceous age. Conformably overlying the Guayuta group is the Santa Anita formation consisting of a lower sandstone member (Upper Cretaceous), a middle shale member (Upper Cretaceous-Paleocene), and an upper member of calcareous and dolomitic siltstones, glauconitic sandstones, and shales (Paleocene-Eocene). The whole formation is about 2,400 feet thick.

The Santa Anita formation is overlain by the Merecure formation. In the eastern part of the area the contact between the two appears transitional but in the vicinity of Barcelona there may be an erosional unconformity. The basal Merecure contains orbitoidal foraminifera indicative of late Eocene age. The upper part of the formation is formed by the thick Naricual coal-bearing member and is probably in part Oligocene in age. The total thickness of the Merecure formation is 5,500–7,500 feet.

The non-marine sediments of the upper part of the Merecure formation grade upward without a break into the more marine Santa Inés formation consisting of about 24,000 feet of sandstones, grits, conglomerates, shales, and claystones of middle Oligocene to late Miocene age. The marine character of this formation increases from west to east, and in the eastern part of the area it includes a fairly deep-water, highly foraminiferal shale member (Carapita shale).

The Santa Inés formation is unconformably overlain by the Sacacual group (Pliocene) which is in turn unconformably overlain by the Mesa formation (Pleistocene).

The sedimentary sequence of northeastern Anzoátegui indicates that in early Cretaceous time a marine transgression began in this area which reached its culmination with respect to depth of water in Turonian time (Querecual formation). Toward the close of the Cretaceous (San Antonio and Santa Anita formations) there was a tendency toward emergence and a shallowing of the sea although its extent was still great. Marine deposition appears to have continued into Paleocene time, however, and in the eastern part of the area appears to have persisted with little or no indication of a break until the late Eocene. In the Barcelona area there may have been emergence and erosion in the early

[1] Manuscript received, February 5, 1943. Published with the permission of Mene Grande Oil Company, C. A. Permission for publication received, October, 1943.

[2] Mene Grande Oil Company.

or middle Eocene (Santa Anita-Merecure unconformity). In the late Eocene (lower Merecure) marine deposition was widespread but was soon replaced by a coal-basin environment which continued into Oligocene time. In the middle Oligocene another major marine transgression began, during which the sediments of the Santa Inés formation were deposited. The area was then folded in late Miocene time before the deposition of the Sacacual group (Pliocene) and probably again in Pliocene time before Mesa (Pleistocene) deposition.

The depositional history of the area is related to the pressure of the northern borderland of Paria against the continental nucleus of the Guayana shield and the consequent persistent southward shifting of the axis of the intervening Eastern Venezuelan geosyncline. During Cretaceous and early Tertiary time northeastern Anzoátegui lay on the stable southern side of the geosyncline where deposition was relatively continuous, and formations follow each other without angular relation. In Oligocene and Miocene time it occupied a nearly axial position and received the thick flysch-like deposits of the Santa Inés formation. Toward the close of the Miocene it actually became a part of the northern flank of the geosyncline and as such its sediments were folded with each subsequent movement of the mobile northern borderland.

Introduction

During the years 1930–1934 a reference section for the stratigraphy of the mountain-front area of northeastern Anzoátegui was established on Rio Querecual and in the vicinity of the towns of Bergantín and Santa Inés (7). The 40,000 feet of Cretaceous and Tertiary sediments exposed in this area were divided into formational units, the boundaries of these units were defined geographically and geologically, and each formation was discussed with respect to lithology, mineralogy, paleontology, age, stratigraphic relations, *et cetera*.

In 1937 construction was started on the Mene Grande Oil Company highway from Puerto la Cruz (near the city of Barcelona) southward to the Oficina oil field, opening an excellent supplementary section through the mountain-front ridges 25 kilometers west of the type Rio Querecual section. This road section has now been studied in detail and the area between it and the Rio Querecual has been mapped geologically. Sections have also been studied on a number of rivers east of Rio Querecual and on the islands north of Puerto la Cruz (Fig. 1). The results of this work are helping to give a three-dimensional picture of the formations previously described from Rio Querecual and have filled out that part of the stratigraphic section which was missing or poorly exposed on that river.[2]

During the course of this work many fossils have been collected. These have been of great value in local zoning and horizon identification. They are also leading to a more accurate determination of formation ages than was possible at the time the formations were originally established. To this latter end the writers have been fortunate enough to secure the coöperation of specialists in the United States as follows.

Large foraminifera—T. W. Vaughan, United States National Museum
Small foraminifera—J. A. Cushman
Echinoids—C. W. Cooke, United States Geological Survey
Corals—J. W. Wells, Ohio State University
Mollusks (Mesozoic)—R. W. Imlay, United States National Museum
Mollusks (Tertiary)—Julia Gardner, United States National Museum
Plants—Erling Dorf, Princeton University

[2] For assistance in topographic-geologic mapping acknowledgment is due A. Birketvedt, A. J. Krumholz, B. B. Martinez, C. H. Neff, and G. Relf. R. B. Van Buren and W. F. Auer have assisted in micropaleontological work.

Material has been sent to them for study and preliminary results on many of the collections have already been received.

The present preliminary report outlines the formational units now recognized, summarizes the major points regarding their stratigraphy, and discusses briefly the new paleontologic evidence on their ages. Since the war has indefinitely delayed the completion of the project as it was originally planned, including the sending of additional fossil material to the United States for identification, a progress report appears desirable at this time so that the information secured to date may be available to those working on adjacent areas. It is hoped that a more complete report may be issued later, accompanied by maps and sections and the complete paleontological reports of the several collaborating specialists.

STRATIGRAPHY

PRE-CRETACEOUS?

Rocks older than Cretaceous are as yet unknown in northeastern Anzoátegui or anywhere in the Serranía del Interior of Eastern Venezuela. However, the Cordillera de la Costa which forms the peninsulas of Paria and Araya north of the Serranía del Interior is made up almost entirely of metamorphosed sediments of the so-called Caribbean series. This series probably immediately underlies the Cretaceous rocks of northeastern Anzoátegui, though nowhere actually exposed.

There are few accurate data available on the rocks of the Caribbean series and it is hoped that someone may be inspired soon to make a detailed field and and laboratory study of them. Along the road from Cariaco to Carúpano they consist rather uniformly of greenish gray chloritic schists or phyllites containing variable amounts of quartz. On the Carúpano-El Pilar road the northern part of the section is made up of micaceous and chloritic schists, phyllites, and schistose quartzites, but the southern part contains much dark partly metamorphosed thin-bedded and laminated limestone and cherty limestone. Quartz veins are everywhere common in the series.

No fossils have been reported to date in the Caribbean series in Eastern Venezuela though it seems probable that they may be found in limestone facies such as that exposed on the Carúpano-El Pilar road between La Gloria and Cumbre Rincón. The age of the series is thus unknown although there are reasons for thinking that it may be Triassic-Jurassic (9). Upper Jurassic ammonites have been found in limestones associated with phyllites of the Caribbean series in the Northern Range of Trinidad (17).

The metamorphic rock area of the Cordillera de la Costa is flanked on the south by the outcrop belt of the Barranquín formation of Lower Cretaceous age forming the northern part of the Serranía del Interior. However, the two ranges are separated by a strong topographic depression marked by the Gulf of Cariaco, and a series of lowlands and lagunas farther east, which is doubtless the reflection of a major fault zone making the boundary between the metamorphic rocks

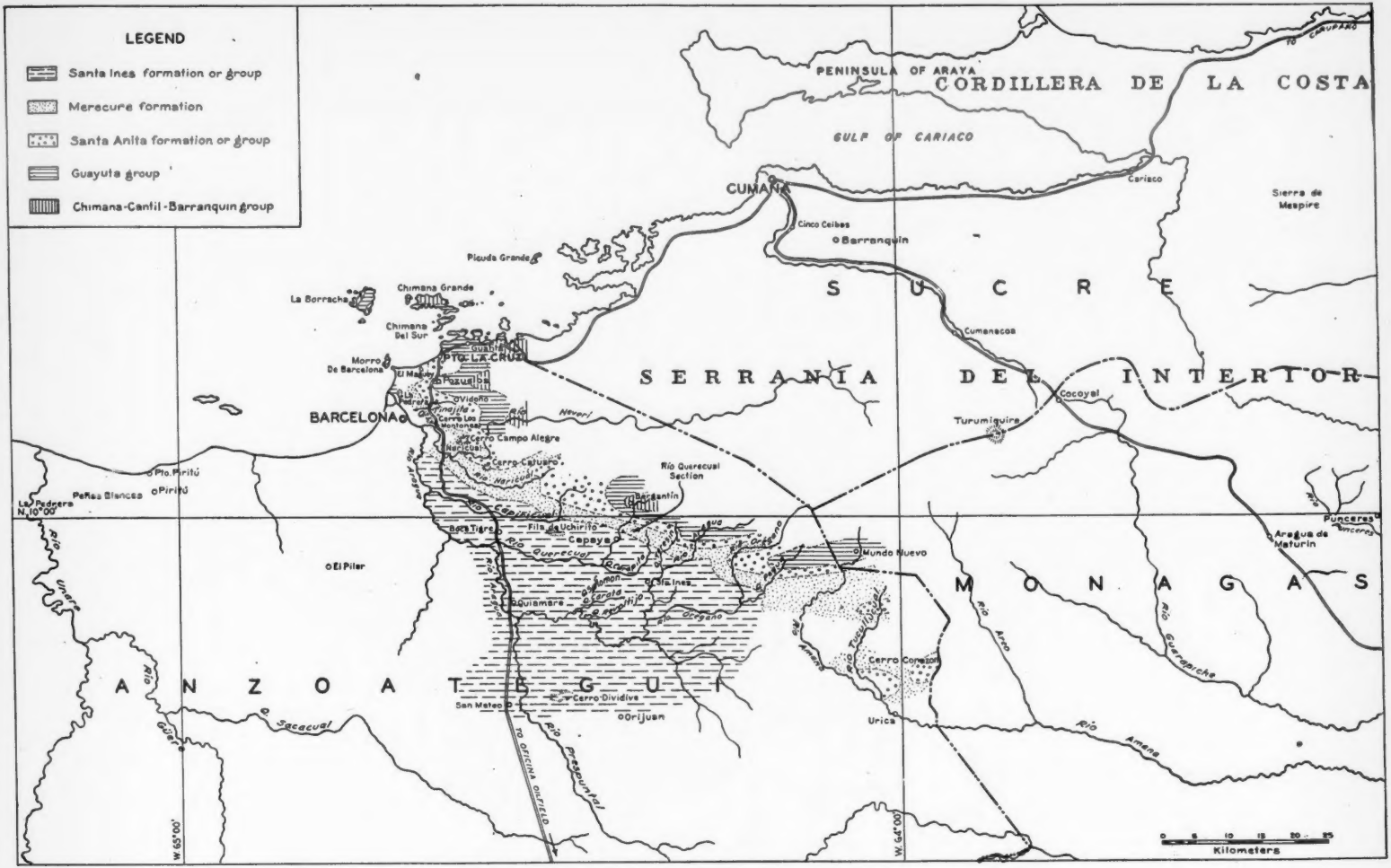


FIG. 1.—Index map of northeastern Anzoátegui showing areal distribution of geologic formations.

and the unmetamorphosed Barranquín formation. The actual contact between the two formations has not been seen because of the alluvial cover in this valley, but it is possible that this contact is exposed in the Sierra de Meapire which to some extent appears to form a connecting link between the two ranges. It is probable that the relation between the two formations is one of profound unconformity but any contact which might be found is probably a fault contact.

BARRANQUÍN FORMATION

(Figure 2)

The type locality was designated by Liddle (11, pp. 109–11) as the vicinity of the town of Barranquín, state of Sucre, on the Aragua de Maturín-Cumaná trail from Dos Rios on the south to within 2 kilometers of San Fernando on the north. The thickness of the formation has been estimated as 3,500–4,500 feet but the basal part and normal contact with underlying formations has not been seen. The formation is widespread throughout the Serranía del Interior and holds up some of the highest peaks of this range. In northeastern Anzoátegui the formation has been studied by the writers principally on the islands off the coast near Puerto la Cruz. Valuable supplementary sections have also been examined on the Cumanacoa-Cumaná and Guanta-Cariaco roads.

The Barranquín formation includes a variety of lithologic types but consists dominantly of sandstones and variously colored shales. Limestones are common in the upper part. The formation appears to represent an alternation between non-marine coastal-swamp deposits and shallow-water marine sediments with conditions becoming more persistently marine toward the top of the formation. Characteristic lithologic types constituting the upper 2,000 feet of the formation as exposed on Chimana Grande, Picuda Grande, and other islands off the Puerto la Cruz coast are as follows.

1. Light-colored, reddish-weathering, coarse-grained, quartzitic sandstones. Highly cross-bedded. Commonly conglomeratic with quartz pebbles. Locally whitish-colored due to decomposed feldspar
2. Shaly, highly micaceous, fine- to medium-grained sandstones
3. Dark gray carbonaceous shales with well preserved plant remains and gray splintery micaceous shales weathering to lavender, purplish, or reddish colors
4. Gray, olive-brown weathering, fossiliferous sandy limestones, with fossils commonly preserved as iron oxide replacements

The top of the formation is placed in the zone of change from the sandstones and plant-bearing shales, which characterize the Barranquín formation, to the limestones and alternating limestones and shales of the more persistently marine environment of the overlying El Cantil formation. This contact in many places must be drawn very arbitrarily, and, as a result of rapid lateral lithologic variation, it probably varies considerably in stratigraphic position from place to place.

Fossil occurrences in this formation, already included in published descriptions, have been listed previously (7, p. 1983). New information may be summarized briefly as follows.

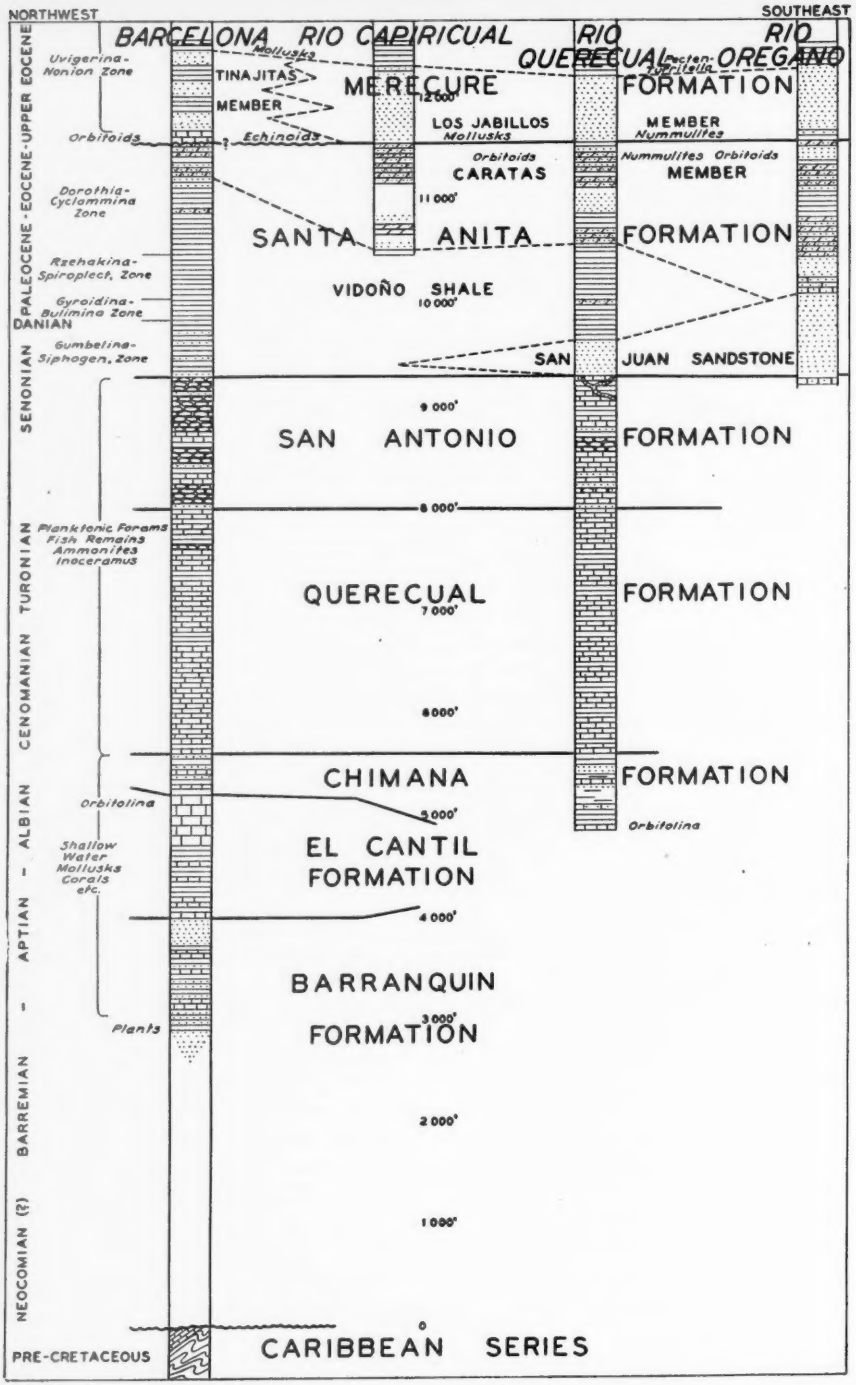


FIG. 2.—Columnar section of northeastern Anzoátegui (lower part).

1. At the northwest end of Caribe Islet, just northwest of La Borracha Island, there is an excellent exposure of caprinid limestone. R. W. Imlay has identified *Caprina* cf. *plumensis* Harris and Hodson, and *Amphitriscoelus* cf. *waringi* Harris and Hodson.
   Imlay also identified the same *Amphitriscoelus* from Barranquin limestone 9 kilometers south of Cumanacoa on the road to Cumaná. The species was originally described from Trinidad where specimens were considered to "represent a Cenomanian horizon, though they may well be as low as the Aptian" (6). Imlay thinks a lower Aptian age probable.
2. Sandy limestones in the upper part of the formation on Lobo Islet, just northwest of La Borracha and also on the island of Chimana Grande have yielded several collections of thick-shelled mollusks, including species of *Exogyra, Trigonia, Cucullaea, Arctica, Sphaera, et cetera.* According to Imlay's preliminary determinations, these are "very likely of Aptian age, as indicated by the association of *Exogyra aquila* (Brongniart), an Aptian-lower Albian marker, with species of *Trigonia, Sphaera,* and *Cucullaea* that greatly resemble certain species characteristic of the upper Neocomian and Aptian."
3. A collection of corals from a Barranquín limestone at Las Cinco Ceibas about 10 kilometers south of Cumaná on the road to Cumanacoa is particularly significant with respect to the age of this formation. This collection has been studied by J. W. Wells who has made the following preliminary identifications.

   Astrocoenia n. sp.
   Cyathophora haysensis Wells
   Cyathophora n. sp.
   Stylina n. sp.?
   Stylangia n. sp. aff. *S. anomalos* (Felix)
   Stylosmilia sp. cf. *S. alpina* Koby
   Enallhelia n. sp. aff. *E. rathieri de Fromental*
   Myriophyllia (*Eugyra*) n. sp. aff. *M. mariscali* (Felix)
   Calamophyllia sp. cf. *C. venezuelensis* (Gregory)
   Synastrea irregularis (Felix) n. var.
   Meandrophyllia plummeri Wells n. var.
   Meandrophyllia n. sp.
   Actinaraea sp. cf. *A. arborescens* (Felix)
   Cladophyllia n. sp.
   Thecosmilia n. sp.
   Elasmophyllia tolmachoffana Wells
   Budaia n. sp.
   Milleporidium n. sp.

   Wells comments on this collection are as follows: "The rich coral fauna of the Barranquín formation consists wholly of hermatypic or reef-building corals. They represent a facies indicative of quiet waters—shallow lagoons behind reefs. . . . Broadly viewed, the fauna is the local expression of the very widely distributed Tethyan 'Urgonian' coral facies, found in Europe, Africa, Japan, and southern North America. Its more immediate connections are with that of the lower Glen Rose of Texas and the Barremian-Aptian of Tehuacan, Puebla, Mexico. The Tehuacan coral fauna is older than that of the Glen Rose and probably older than that of the Barranquín. That the Barranquín corals are of the same age as those of the Glen Rose is probable; they certainly are not younger. . . . The Barranquín fauna shows more relationships with that of the European 'Urgonian' than the homotaxial Texan and Mexican faunas—evidenced by the presence of the genera *Enallhelia, Stylosmilia,* and *Milleporidium,* and of species allied closely to the European forms."
4. Fossil plants have been collected from the formation on the islands of Chimana Grande, Picuda Grande, and also from near Cumanacoa. These are being studied by Erling Dorf but no report has been received yet.

A review of the paleontological data available reveals that the marine fossiliferous upper part of the Barranquin formation shows strongest affinities to the Aptian and Barremian-Aptian (Urgonian) stages of Europe. It is not improbable that the lower and less marine part of the formation extends down into the Neocomian stage.

EL CANTIL FORMATION

(Figure 2)

The formation was named by Liddle (11, pp. 124–35) from the town of El Cantil 3 kilometers east of Punceres in the state of Monagas. The type section

which is exposed on the El Cantil-Punceres structure and in Rio Punceres is incomplete due to faulting. According to Liddle, it is about 800 feet thick and is three-fourths limestone and one-quarter shale.

The El Cantil formation is more or less continuous throughout the length of the Serranía del Interior. In northeastern Anzoátegui it is best exposed on the islands off the coast near Puerto la Cruz and along the Guanta-Cumaná highway just east of Pertigalete. At the eastern end of the island of Chimana Grande the formation is about 1,200 feet thick. Here the upper 500 feet is almost entirely the massive dense gray "reef" limestone which is the most distinctive feature of the formation. The lower 700 feet consists of dark, fissile shale with thin interbedded yellowish fossiliferous limestones. This lower facies, however, also grades laterally into reef limestones. The El Cantil limestone is typically bluish gray and weathers characteristically to castellated and pinnacled forms.

The El Cantil formation is entirely marine. The "reef" or bioherm character of the massive limestones of the upper part is evident from the rapid lateral variation to clastic sediments, the massive structureless character of the rock, and the local abundance of characteristic bioherm-forming fossils such as corals and large foraminifera. The formation is transitional downward into the Barranquín formation and upward into the Chimana formation. The top of the El Cantil formation is placed at the top of the characteristic thick, massive, dense gray "reef" limestones, where these give way to shales, thin olive-brown limestones, and glauconitic sandstones of the Chimana formation. The El Cantil formation represents a marine limestone and shale facies in an essentially continuous series of deposits, which is not only gradational above and below into the more clastic, less calcareous facies of the Barranquín and Chimana formations but is also laterally gradational into those formations.

The principal paleontologic evidence on the age of the El Cantil formation may be reviewed briefly as follows.

1. Collet (1) studied a collection made by Rheinhard near Aragua de Maturin, state of Monagas, and considered the ammonites as representing without doubt lower and upper Aptian.
2. Gregory (5) determined corals from the type locality of the formation at Punceres, Monagas, as Urgonian (Barremian-Aptian) in age.
3. Liddle (11, p. 126) lists numerous species and considers the formation Aptian-Albian "correlating with the Fredericksburg and Washita divisions of southwestern United States."
4. The common presence of *Orbitolina concava* (Lamarck) var. *texana* (Roemer) (7, pp. 1986–87) suggests equivalence of the upper part of the formation to the Glen Rose of Texas (lower and in part middle Albian).
5. A sample of probable El Cantil limestone from 6 kilometers north of Cumanacoa was examined by Imlay who found *Coalcomana* cf. *ramosa* (Boehm) which he considers possibly suggestive of Cenomanian age.

These paleontologic data, together with the age determinations for the underlying and overlying formations, lead to the conclusion that the El Cantil formation is largely Aptian and lower Albian in age.

CHIMANA FORMATION

(Figure 2)

The name of the formation is derived from the island of Chimana Grande 7 kilometers north of Puerto la Cruz. The type section is almost perfectly exposed

at the eastern end of the island on the south slope of the high east-west El Cantil limestone ridge which forms the backbone of the island. The provisional name of "Bergantín beds" was previously used for this unit on the Rio Querecual section, awaiting the discovery of a more adequately exposed type section (7, p. 1985). This provisional term is now replaced by Chimana formation.

The type section consists largely of fissile micaceous shale weathering to lavender, maroon, yellowish gray, orange, and olive-brown tints. There are some discontinuous olive-brown fossiliferous limestones in the lower part of the formation and there are thin seams of reddish ironstone interbedded in the shales. Brownish glauconites and glauconitic micaceous sandstones are common in the upper part. There are 400 feet of Chimana formation in the type section but the thickness of the formation is known to vary from 200 to 1,000 feet due to lateral gradation to El Cantil facies. Because of this lateral gradation it is difficult in many places to draw a contact between Chimana and El Cantil formations and it is probable that locally each is entirely replaced by the other. Thus, there is still doubt whether the thin *Orbitolina* limestone on the Rio Querecual at the crest of the Bergantin anticline should be considered part of the Chimana formation or a poor development of the El Cantil formation. The formation is throughout a deposit of shallow-water marine origin as is indicated by the coarse sandstones, abundance of glauconite, shallow-water mollusks, absence of small foraminifera, and lateral gradation to reef limestones.

The contact of the Chimana formation with the overlying Querecual formation is one of the most readily determined formation contacts in northeastern Venezuela. This contact is well exposed at Piedra Escrita at the western end of La Borracha Island. Here massive green glauconite of the Chimana formation grades upward into yellowish-weathering very fissile gray shale which is in turn overlain by 50 feet of gray sandy shale in which hard sandy calcareous lenses stand out prominently in association with thin seams of fibrous calcareous rock. This thin zone appears to mark a transition to the Querecual formation. It is overlain by dark gray calcareous shale with sandy lenses but containing the large discoidal limestone concretions typical of the Querecual formation and showing typical Querecual fossils. The abruptness of this contact locally has suggested an unconformity but it appears to be due rather to a rapid change in environment at a time when deposition was slow, without any actual erosional break.

Fossil occurrences in the "Bergantín beds" (now Chimana formation) were previously discussed in connection with the Rio Querecual section (7, pp. 1986–88) and the conclusion was reached that these beds were approximately Aptian-Albian in age. Lateral equivalence to the El Cantil formation gives further support to this view. Preliminary reports on a few recent collections from the Chimana formation are as follows.

1. Imlay has identified *Exogyra aquila* (Brongniart) "an Aptian-Lower Albian marker" from a collection from La Borracha Island, as well as many other molluscan species commonly assigned to the upper Aptian and lower Albian.
2. An ammonite from just below the Querecual formation contact on Quebrada Provisora southeast of Puerto la Cruz has been identified by Imlay as *Oxytropidoceras* cf. *O. carbonarium*

(Gabb) and is considered by him as indicative of Albian (upper part of Middle Albian) age.

3. From a collection on La Borracha Island, Wells has identified *Stephanacoenia guadalupae* Wells, *Myriophyllia* (Eugyra) n. sp. aff. *M. mariscali* (Felix), *Meandrophyllia plummeri* Wells, and *Dendraraea* n. sp. He remarks that "the small and probably very incomplete coral fauna from the Chimana formation does not appear to differ from that of the Barranquín formation."

On the basis of available fossil evidence it appears that the Chimana formation, like its lateral equivalent the El Cantil formation, is Aptian-Albian in age. In its upper part it is probably definitely Albian and may even reach to the Cenomanian although there is no paleontologic evidence of upper Albian. At the same time it is notable that pelecypods, gastropods, and corals from the lower part of the Chimana formation very closely resemble those from the upper part of the Barranquín formation of Urgonian age.

GUAYUTA GROUP

The term "Guayuta group" has been assigned to the thick series of black carbonaceous-bituminous shaly limestones and calcareous shales of Upper Cretaceous age in northeastern Venezuela (7, p. 1989). Throughout northeastern Anzoátegui this group is usually divisible into the Querecual and San Antonio formations.

QUERECUAL FORMATION

(Figure 2)

The formation is very well exposed in its type section on Rio Querecual and its geographic and geologic limits have been defined previously (7, pp. 1989–92). It crops out widely in northeastern Anzoátegui in the vicinity of the Bergantín and Pozuelos anticlines and particularly near Guanta and Puerto la Cruz, and on the islands of La Borracha, Chimana Grande and Chimana del Sur.

The formation is very homogeneous and consists almost entirely of hard black thin-bedded and laminated carbonaceous-bituminous shaly limestone and calcareous shale. Discoidal, spheroidal, and ellipsoidal limestone concretions ranging from a few inches to several feet in diameter are particularly characteristic. The formation weathers to a whitish gray color contrasting with the reddish weathering of the older Cretaceous formations. The thickness of the formation on the Rio Querecual is about 2,400 feet. However, in general, measurements of this formation are very difficult due to its incompetence and susceptibility to structural deformation. The perfect exposures on the vegetationless slopes of the coastal islands near Puerto la Cruz make clear that much of the apparent thickness of the formation may be due to repetition by structural contortions.

The contact with the underlying Chimana formation is sharp (fault contact on Rio Querecual) but the two formations are apparently conformable. The division line between the Querecual formation and the overlying San Antonio formation is placed at the base of the first more or less continuous sandstone bed in the Guayuta group and the distinction between the two formations is based largely on the presence of sandstones and more abundant chert beds in the latter. Where exposures are poor this contact may be difficult to draw.

Specimens from near the base of the formation on Chimana Grande and along the mainland coast 4 kilometers east of Guanta have been identified by Imlay as *Inoceramus labiatus* Schlotheim and are considered by him to be indicative of Turonian age. This accords with previous identifications of this species from the Querecual formation by Dietrich and Maury (7, p. 1991). On the other hand, Heinz (10) identified species of *Inoceramus* from the Karsten collection which he considered indicative of Cenomanian age. From the lower part of the formation on the island of La Borracha Imlay has identified *Turrilites* sp., *Inoceramus* cf. *I. peruanus* Bruggen, desmoceratid and acanthoceratid ammonites, and *Prionotropis?* sp. The latter he considers as evidence of middle or upper Turonian age. There is no indication of unconformity between the Querecual and Chimana formations but since Turonian fossils occur near the base of the Querecual and middle Albian fossils near the top of the Chimana formation it appears that the Cenomanian stage if present must be represented by a relatively condensed section near the contact of the two formations.

The abundance of planktonic foraminifera in the limestones of this formation and its probable conditions of origin have been discussed previously (7 and 9).

SAN ANTONIO FORMATION

(Figure 2)

This formation constitutes the upper part of the Guayuta group. The type section has been defined geographically and geologically in connection with the stratigraphy of the Rio Querecual section (7, pp. 1992–93). The formation consists largely of dark gray shaly and cherty limestone and calcareous shale. However, it also contains a number of beds of massive light gray well sorted fine- to medium-grained calcareous sandstone varying from 1 to 35 feet in thickness. These sandstones are very discontinuous laterally. They are commonly associated with sandstone dikes ranging from 1 to 5 feet thick, which may also less commonly be seen in the upper Querecual and lower Santa Anita formations. Chert development in the San Antonio formation is variable. Locally, as at El Morro de Barcelona and La Borracha Island, the entire formation appears to be chert or silicious limestone. In general in northeastern Anzoátegui, the sandstone content of the formation increases eastward and the chert content westward.

The thickness of the formation in the type section is about 1,300 feet. Like the Querecual formation, it is well exposed in northeastern Anzoátegui on the Bergantín and Pozuelos anticlines and on the coastal islands where the resistant chert beds dominate the Guayuta group topography. The durability of the San Antonio chert is attested by its wide distribution as a detrital element in the Santa Inés and younger formations of Eastern Venezuela.

In the Rio Querecual section, and sections farther east in Anzoátegui, the upper limit of the San Antonio formation is readily identified at the base of the thick gorge-forming San Juan sandstone which constitutes the basal member of the overlying Santa Anita formation. In the Barcelona area, where the San Juan

sandstone is missing or represented only by thin sandstones separated by shales, the contact is less clear and must be placed rather arbitrarily at the point where the characteristic Guayuta group lithology of carbonaceous-bituminous limestones, calcareous shales, and cherts gives way to sandstones and non-calcareous or only slightly calcareous foraminiferal shales.

Fossil occurrences in this formation have been discussed in connection with the Rio Querecual section (7, pp. 1993–94). However, it now appears that the molluscan assemblage mentioned previously probably came from the Querecual rather than the San Antonio formation. Benthonic foraminifera have been found in considerable abundance in the shaly portions of the uppermost part of the formation and include a number of forms common to the lower part of the Colón shale of western Venezuela and Colombia. The San Antonio formation is probably in large part early Senonian in age.

SANTA ANITA FORMATION

(Figure 2)

The type section of the formation is on Rio Querecual (7, p. 1994). It was originally divided into two members, a lower San Juan sandstone member and an upper Caratas member. It now appears desirable to restrict the term "Caratas member" to the resistant unit of calcareous and dolomitic siltstones and glauconitic sandstones at the top of the formation and to recognize a middle shale member, here named Vidoño shale from the village of Vidoño 6 kilometers east of Barcelona. The Santa Anita formation may eventually be raised to the rank of a group and its three members to formation rank.

San Juan sandstone.—The type section on Rio Querecual extends from the contact with the San Antonio formation, 150 meters upstream from Paso Santa Anita, southward to Paso Santa Anita. The member here consists of about 320 feet of very hard, gray to light gray, fine- to medium-grained well sorted, sparingly glauconitic, and locally calcareous sandstone in beds ordinarily from 1 to 3 feet thick. Westward from Rio Querecual the member grades within a short distance into shale with only minor beds of sandstone and is included in the Vidoño member. Toward the east however the San Juan sandstone thickens at the expense of the Vidoño shale to about 1,000 feet. Here it constitutes one of the most resistant units of the Serranía del Interior, forming peaks such as that of Cerro Soledad and difficultly passable gorges on the main rivers.

Vidoño shale.—On Rio Querecual this member includes the interval from Paso Santa Anita southward to the southern end of the island about 300 meters downstream from Paso Santa Anita. It is here about 900 feet thick and is made up almost entirely of dark foraminiferal shale with minor beds of sandstone and hard calcareous siltstone. Shales, siltstones, and sandstones are commonly highly glauconitic. Westward in the vicinity of Barcelona this shale member thickens at the expense of both the San Juan and Caratas members. It forms the Vidoño valley and is well exposed on the Puerto la Cruz-Oficina highway on the crest and

south slope of Cerro Pele Ojo. It also crops out in the vicinity of Puerto la Cruz and on La Borracha Island. East of Rio Querecual the member grades into sandstones and siltstones of the San Juan and Caratas members.

Caratas member.—The extent of this member in the type section is now restricted to the interval from the southern end of the island, 300 meters downstream from Paso Santa Anita, to the base of the Merecure formation about 800 meters downstream from Paso Santa Anita. It includes about 1,100 feet of section characterized principally by distinctive black or blue gray, very hard calcareous and dolomitic siltstones and impure silty and commonly dolomitic limestone. Near the middle of the member is 130 feet of very hard fine- to medium-grained sandstone resembling the San Juan sandstone. Glauconite is abundant throughout the member. A similar section is exposed on Rio Capiricual but still farther west in the Barcelona area the member is considerably thinner due to lateral gradation to Vidoño shale and the possible cutting out of section by unconformity. In the Barcelona area it consists largely of hard black calcareous or dolomitic siltstones and impure highly glauconitic sandstones and sandy shales. It forms such hills as Las Trincheras, Vidrial, and Pele Ojo, and is exposed on the flanks of Campo Alegre and Catuaro. Eastward from Rio Querecual, sections on the Aragua, Orégano, Pegua, and Tucúllucual rivers show progressively increasing thickness and sandstone content for the member. Gritty and pebbly beds are even present in its upper part.

The contact between the Santa Anita formation and the overlying Merecure formation is in general placed at the top of the distinctive calcareous or dolomitic siltstones of the former and the base of the prominent Los Jabillos sandstone member or the Tinajitas orbitoidal limestone member of the latter. In the Barcelona area this contact is very sharp and may be one of erosional unconformity. This is also the case as far west as Rio Capiricual. On Rio Querecual there are some 50 feet of shaly sediments just below the Los Jabillos sandstone which it is doubtful to which formation to assign. Farther east on Rio Aragua, Rio Orégano, and other streams, there appears to be a transition zone between the two formations in which dense black calcareous siltstone typical of the Santa Anita formation alternates with pebbly quartzitic sandstone like that of the Los Jabillos member of the Merecure formation.

The shaly parts of the Santa Anita formation contain a rich fauna of small foraminifera which has been divided into faunizones from the base upward as follows.

1. "*Gümbelina-Siphogenerinoides* zone."—This zone extends upward to about 100 feet above the San Juan sandstone in the Rio Querecual section and is well developed in the basal shales of the formation farther west. It is definitely Cretaceous on the basis of *Gümbelina excolata* Cushman, *Siphogenerinoides bramletti* Cushman, *Siphogenerinoides cretacea* Cushman, *Globotruncana* sp., *Palmula* sp., and other forms and is probably approximately equivalent in age to the upper Colón and lower Mito Juan faunas of western Venezuela and Colombia and therefore of upper Taylor and Navarro age (Upper Senonian) (3).
2. "*Gyroidina-Bulimina* zone."—This is a relatively indistinct and poorly developed zone within the lower part of the Vidoño shale. It is characterized by *Bulimina kickapooensis* Cole, *Planulina spissicostata* Cushman, and species of *Gyroidina, Anomalina, Recurvoides, Textularia, et*

cetera. It forms a transition between the "*Gümbelina-Siphogenerinoides* zone" below and the "*Rzehakina-Spiroplectammina* zone" above. It is rather lacking in diagnostic species but from its stratigraphic position may be considered as probably approximately representing the Danian stage.

3. "*Rzehakina-Spiroplectammina* zone."—This zone constitutes the upper part of the Vidoño shale on Rio Querecual and the middle part of the member in the Barcelona area. It is characterized by species of *Rzehakina, Spiroplectammina, Clavulinoides, Cyclammina, Vaginulina, Cibicides, Eponides, Ammobaculites, et cetera.* It has a Cretaceous aspect but appears to lack any species definitely known to be limited to the Cretaceous. A somewhat similar fauna has been found in a well in western Monagas above beds containing *Venericardia* resembling *V. parinensis* and *V. ameliae* described from the Paleocene of Trinidad by Rutsch (13). There is also considerable resemblance between the fauna of this zone and that of the Lizard Springs beds of Trinidad considered of Maestrichtian-lower Paleocene age by Renz (12, p. 531). This zone is therefore tentatively considered as Paleocene in age.
4. "*Dorothia-Cyclammina* zone."—This zone is characterized by persistent species of *Dorothia, Cyclammina,* and *Gaudryina* with few other forms. It occupies the uppermost part of the Vidoño shale and occurs sporadically in the shaly parts of the Caratas member. Most of the species are also found in the underlying "*Rzehakina-Spiroplectammina*" zone, but associated with many other species there. None of the species appears very diagnostic as regards age but from orbitoid occurrences at the top of the zone it now appears that the zone may include sediments of lower and middle Eocene age. It is noteworthy that many of the calcareous siltstones of the Caratas member show abundant planktonic foraminifera in thin section, like the limestones of the Guayuta group.

The foregoing identifications and zonations are only provisional but have been of great assistance in working out stratigraphy and structure. Collections of the small foraminifera have been sent to J. A. Cushman for more thorough study.

Calcareous glauconitic grits and siltstones near the top of the Caratas member on Rio Querecual have yielded poorly preserved orbitoids and nummulites which have been identified by T. W. Vaughan as *Discocyclina* sp., *Lepidocyclina* sp., *Camerina* sp., and *Miscellanea* sp. (*Asterocyclina* sp. has previously been identified) (16, p. 1565). Orbitoid and nummulite beds have also been found in the uppermost part of the member on Rio Aragua and Rio Orégano but have not yet been studied by Vaughan.

Megafossils are scarce in the Santa Anita formation. A limestone believed to belong in the Caratas member crops out on Punta de Piedras north of Urica and the common *Venericardia* in this bed has been considered by Rutsch as probably identical with one from Màrac Quarry in Trinidad (13, p. 173). He considers this species as indicative of Paleocene (Midway) age (14, p. 517). Cooke (2) has named and described *Oligopygus nancei* from an echinoid collection made on Rio Amana by J. W. Nance and reported by him to be just below the top of the Santa Anita formation. In the matrix of the echinoid specimens Vaughan identified *Operlinoides, Miscellanea?, Discocyclina* (*Asterocyclina*), and *Lepidocyclina?*, and states that these indicate middle or upper Eocene age. Cooke (private communication) states that all the known species of *Oligopygus* are restricted to upper Eocene deposits but that the genus may have a greater range, for the echinoid fauna of the middle and lower Eocene is very imperfectly known. This bed on Rio Amana has not yet been examined by the writers but it appears quite possible that it would fall in the lower part of their Merecure formation rather than within their Santa Anita formation.

In reviewing the evidence for the age of the Santa Anita formation, it appears that the lower part is definitely late Cretaceous in age, the middle part is Cretaceous-Paleocene, and the upper part on the basis of the orbitoid fauna may extend as high as middle and upper Eocene. It is not improbable that the calcareous and dolomitic siltstones of the Caratas member represent a relatively condensed lower and middle Eocene section.

MERECURE FORMATION

(Figures 2 and 3)

The formation was originally named from Quebrada Merecure, a small dry tributary of the Rio Querecual (7, p. 2000). However, much more complete sections are known farther west on Rio Capiricual and in the vicinity of Naricual. The formation consists largely of sandstones and shale but is particularly characterized by the former because of their topographic expression and more common outcrop. The coal beds of the middle and upper parts and the reef limestone of the extreme basal part in the vicinity of Barcelona also are distinctive features. The total thickness of the formation is from 5,500 to 7,500 feet. The formation has been divided into three members: Tinajitas member (basal member in Barcelona area), Los Jabillos member (basal member on Rio Capiricual and eastward), and Naricual member (upper member).

Tinajitas member.—In the Barcelona area the base of the Merecure formation is characterized by orbitoid-algal reef limestones which may attain thicknesses of 50–100 feet but which pinch out in a short distance to discontinuous limestone lenses less than a foot thick. These limestones immediately overlie the Santa Anita formation siltstones on Cerros Las Trincheras, El Maguey, Vidrial, Tumba de Bello, Pele Ojo, Montones, and other hills in the vicinity of Puerto la Cruz. The remainder of the Tinajitas member above the orbitoid limestones consists of interbedded lavender-gray quartzitic sandstone, gray and greenish gray slightly glauconitic sandstone and siltstone, and gray silty and in places foraminiferal shale. The type section is on Quebrada Tinajitas and along the Puerto la Cruz-Oficina highway just east of Barcelona where at least 650 feet of the member is present. The Tinajitas member grades laterally southeastward into the Los Jabillos sandstone and in the vicinity of Naricual the two facies distinctly interfinger.

Los Jabillos sandstone.—This name is given to the unit of pinkish gray thick-bedded medium- to coarse-grained (and even pebbly) quartzitic sandstone about 600 feet thick on Rio Querecual and forming Cerro Los Jabillos immediately east of the river (7, p. 2000). This resistant and topographically prominent unit extends across most of northeastern Anzoátegui and forms a very useful unit for geologic mapping. It is known in typical development on the Areo, Amana, Orégano, Aragua, Teresín, Querecual, and Capiricual rivers but westward in the vicinity of Naricual it divides into several sandstones separated by shales and in

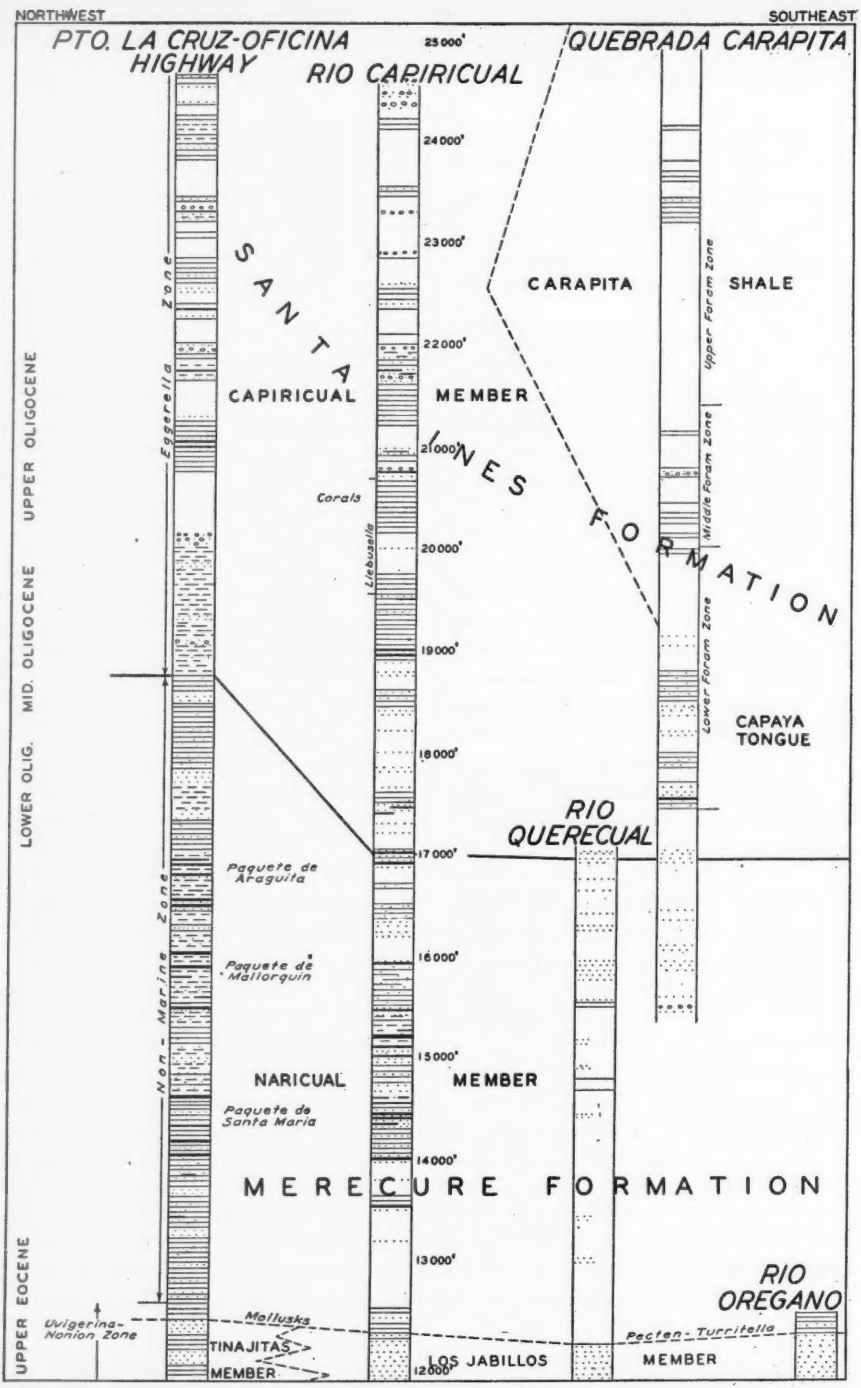


FIG. 3.—Columnar section of northeastern Anzoátegui (middle part).

the Barcelona area grades into the Tinajitas member. In many of the river sections there are thin shaly fossiliferous intervals at the base or near the top of the member which are suggestive of Tinajitas facies. The thickness of the member is 400–750 feet.

Naricual member.—The thick upper part of the Merecure formation above the Los Jabillos and Tinajitas members is here designated as the Naricual member. The type locality is in the vicinity of the coal mining town of Naricual and the type section is well exposed in the valley of Rio Naricual, in the mines, and along the roads of this area. The lower 1,600 feet of the member consists of carbonaceous shales, sandy shales, and sandstones. These are followed by the main coal-bearing series about 3,000–3,500 feet thick which contains the coal groups or "paquetes" of Santa Maria, Mallorquín, and Araguita as named by de Juana and Aguerrevere in their excellent discussion of this area (4). This interval also includes numerous sandstones and shales. The upper part of the member is about 1,500 feet thick. It contains few coals and consists largely of a number of topographically prominent sandstones separated by gray barren shales. The lower more shaly part of the Naricual member commonly forms a broad valley along the mountain front between the resistant Los Jabillos member and the upper Naricual sandstones. The sandstones of the Naricual member are typically massive light-colored quartzose, sugary to quartzitic, medium- to coarse-grained rocks. The member becomes more marine in an easterly direction.

In the Barcelona area there is evidence of disconformity between the orbitoid reef limestones of the Tinajitas member at the base of the Merecure formation and the black calcareous siltstones of the Santa Anita formation. In the Quebrada Tinajitas valley and near Kilometers 11 and 12 along the Puerto la Cruz-Oficina highway the Santa Anita calcareous siltstone near the contact is pitted and weathered and the basal 30 feet of the Tinajitas member consists of a so-called "boulder bed" with blocks and semi-rounded "boulders" of orbitoid limestone in a matrix of mashed orbitoid-bearing shale. There are also angular fragments of siltstone and sandstone resembling the underlying and overlying beds. Traced westward the "boulder bed" grades into continuous orbitoid-algal reef limestone. It seems probable that the "boulders" of limestone actually represent the discontinuous lenticular bodies of limestone deposited at the extreme edge of the main reefs, broken to some extent immediately following deposition but also further broken by the flowage of the surrounding shale between adjacent competent beds during the formation of the recumbent Tinajitas syncline. The "boulders" of siltstone and sandstone may also be in part detrital and in part autoclastic.

Eastward from the Barcelona area indication of unconformity between the Santa Anita and Merecure formations becomes less distinct and on Rio Aragua and Rio Orégano there appears to be a transition zone where Santa Anita calcareous siltstones and Los Jabillos sandstones are interbedded.

In the previous publication on the stratigraphy of the Rio Querecual section (7, p. 2003) it was stated that no direct evidence of unconformity between the

Merecure formation and overlying sediments had been found but the differences between the two formations were such that it was suggested that further work might prove a regional unconformity. However, study of this contact throughout northeastern Anzoátegui has indicated that it is here everywhere transitional. The coal-bearing deposits of the Naricual member give way gradually to the flysch-like but more marine sediments of the Santa Inés formation. Black chert appears as a prominent detrital element in conglomerates and sandstones, and the typical light-colored massive quartzose Merecure sandstones are replaced by the characteristic brown, greenish-brownish gray, and pepper-and-salt impure sandstones of the Santa Inés formation. Because of the transitional relation the exact contact must be placed rather arbitrarily but the general distinction between the two formations is clear. Their differences in large part result from the changed position of the area with respect to the southward-shifting axis of the Eastern Venezuelan geosyncline, as outlined in the final section of this paper. The clean quartzose sandstones of the Merecure formation are still the deposits of the epicontinental sea south of the axis of the geosyncline with derivation largely from the Guayana shield on the south. The impure sandstones of the Santa Inés formation mark the beginning of the flysch-like sediments dumped into the axial part of the basin from the rising mountains on the north. That interbedding of the two types of sandstone and a transition zone between the two formations exists is of course naturally to be expected.

Fossils are extremely rare in the type Merecure section and at the date of the original definition of this formation there was little direct evidence of its age. The more recent work has now yielded a large number of fossil occurrences in other parts of the region and available data on these may be summarized as follows.

1. *Large foraminifera.*—Preliminary studies by T. W. Vaughan of the orbitoid-algal limestones in the basal Tinajitas member of the Barcelona area have identified the following forms.

Lepidocyclina (*Nephrolepidina*) sp.
Lepidocyclina pustulosa forma teratologica tobleri (H. Douville)
Lepidocyclina sp. cf. *L. pustulosa* (H. Douville)
Lepidocyclina (*Nephrolepidina*) sp. cf. *L. tantoyucensis* Vaughan and Cole
Lepidocyclina (several other species)
Asterocyclina?
Operculinoides
Carpenteria sp.

Vaughan considers this assemblage as definitely Eocene and probably upper Eocene. In collections from Merecure limestones at La Pedrera and Peñas Blancas in the vicinity of the Rio Unare 50 kilometers west of Barcelona Vaughan has identified

Discocyclina sp.
Discocyclina (*Asterocyclina*) sp.
Lepidocyclina pustulosa forma teratologica tobleri (H. Douville)
Lepidocyclina cf. *L. crassimargo* Vaughan
Lepidocyclina (other unidentified species)
Operculinoides
Gypsina

In a limestone on Rio Areo in the basal part of the formation probably just below the main Los Jabillos sandstone he has identified

Pseudophragmina sp.
Lepidocyclina pustulosa (Douville)
Discocyclina (*Asterocyclina*) sp.

Vaughan considers both the Unare and Areo assemblages as definitely Eocene and probably upper Eocene. Nummulite and orbitoid beds occur at the base of the Los Jabillos member on Rio Orégano and Quebrada Pegua but these have not yet been studied by Vaughan. Also *Discocyclina* sp. and *Lepidocyclina* (*Lepidocyclina*) sp. occur in siltstones just above the Los Jabillos member on Rio Areo but have not yet been sent to Vaughan.

2. *Small foraminifera.*—Shales in the Tinajitas member of the Barcelona area above the orbitoid limestone contain a distinctive though meager assemblage of small foraminifera characterized by *Nonion* sp. and a *Uvigerina* of the *cocoaensis* type. The same assemblage (provisional *Uvigerina-Nonion* zone) has also been found in shales at the top of the Los Jabillos member in the Naricual area and as far east as the Rio Guarapiche in the state of Monagas. The forms suggest late Eocene or earliest Oligocene. (Specimens from this zone have been sent to Cushman for identification and from preliminary examination he is inclined to consider them Jackson in age.)

3. *Echinoids.*—Limestones and shales of the Tinajitas member in the Barcelona area commonly contain poorly preserved echinoids. C. W. Cooke has made preliminary identification of the following forms with comments as follows.

   Clypeaster cf. *cotteaui* Egozcue (Oligocene of Antigua formation age)
   Clypeaster cf. *concavus* Cotteau. "Suggests early Miocene (Anguilla) or late Oligocene (Antigua)"
   Parastert? sp.

   Echinoids were found in nummulitic limestone at the base of the Los Jabillos member on Quebrada Pegua and *Oligopygus curasavicus* Molengraaf known from the Seroe de Cueba upper Eocene limestone of Curacao has been tentatively identified. Specimens will be sent to Cooke for final identification.

4. *Mollusks.*—The orbitoid-algal limestones of the Tinajitas member near Barcelona show numerous specimens of *Pecten* sp. and rare *Turritella* sp. No specific identifications have been made but according to both C. W. Cooke and Julia Gardner the specimens show resemblance to Oligocene or younger forms. A collection of mollusks from a pebbly bed near the base of the Tinajitas-Los Jabillos member at Angosturas near Naricual has been examined by Miss Gardner who comments as follows. "There is a solitary coral, probably 2 species of nuculanids, a common arca, possibly an *Anadara*, remains of an abundant pecten which I have been unable to determine specifically, possibly 3 lucinoids, a *Callocardia?*, a *Corbula*, a *Dentalium*, one or more species of *Turritella* which exhibit a sculpture pattern shared by Eocene and Oligocene groups, possibly a cassid, and fragments of sculpture which suggest a muricoid or buccinoid. I have seen nothing in the assemblage which would restrict it either to an Eocene or to an Oligocene age."

   The echinoid and nummulite limestone at the base of the Merecure in the Quebrada Pegua section contains numerous specimens of *Tubulostium*, considered by Rutsch (15) to be an Eocene index. It is noteworthy that *Tubulostium* also occurs in the Merecure orbitoid limestone on Rio Unare, in the Mount Moriah beds of Trinidad, and in the *Oligopygus curasavicus* Seroe de Cueba limestone of Curacao.

   A small poorly preserved *Acila* has been found in shales just above the Tinajitas-Los Jabillos member at Naricual, and mollusks (largely *Pecten* and *Turritella*) occur commonly in a siltstone horizon immediately overlying the Los Jabillos sandstone in many of the river sections such as the Capiricual, Aragua, Orégano, and Pegua. These have not yet been sent to the United States for identification.

5. *Plants.*—The nullipore algae of the Tinajitas limestones have not yet been studied. Fossil leaves have been collected by Erling Dorf from the coal measures of the Naricual member but no report has yet been received.

In reviewing the fossil evidence for the age of the Merecure formation, it appears that the Tinajitas and Los Jabillos members are probably upper Eocene on the basis of foraminifera, although the presence of *Clypeaster* in the Tinajitas limestones would indicate a younger age. The molluscan data are not very conclusive although perhaps favoring a younger than Eocene age for the Tinajitas member. Marine fossils are lacking in the Naricual member except in its extreme basal part but it is not improbable that this member may extend into or even through the lower Oligocene. The presence of *Discocyclina* in the basal part of the member

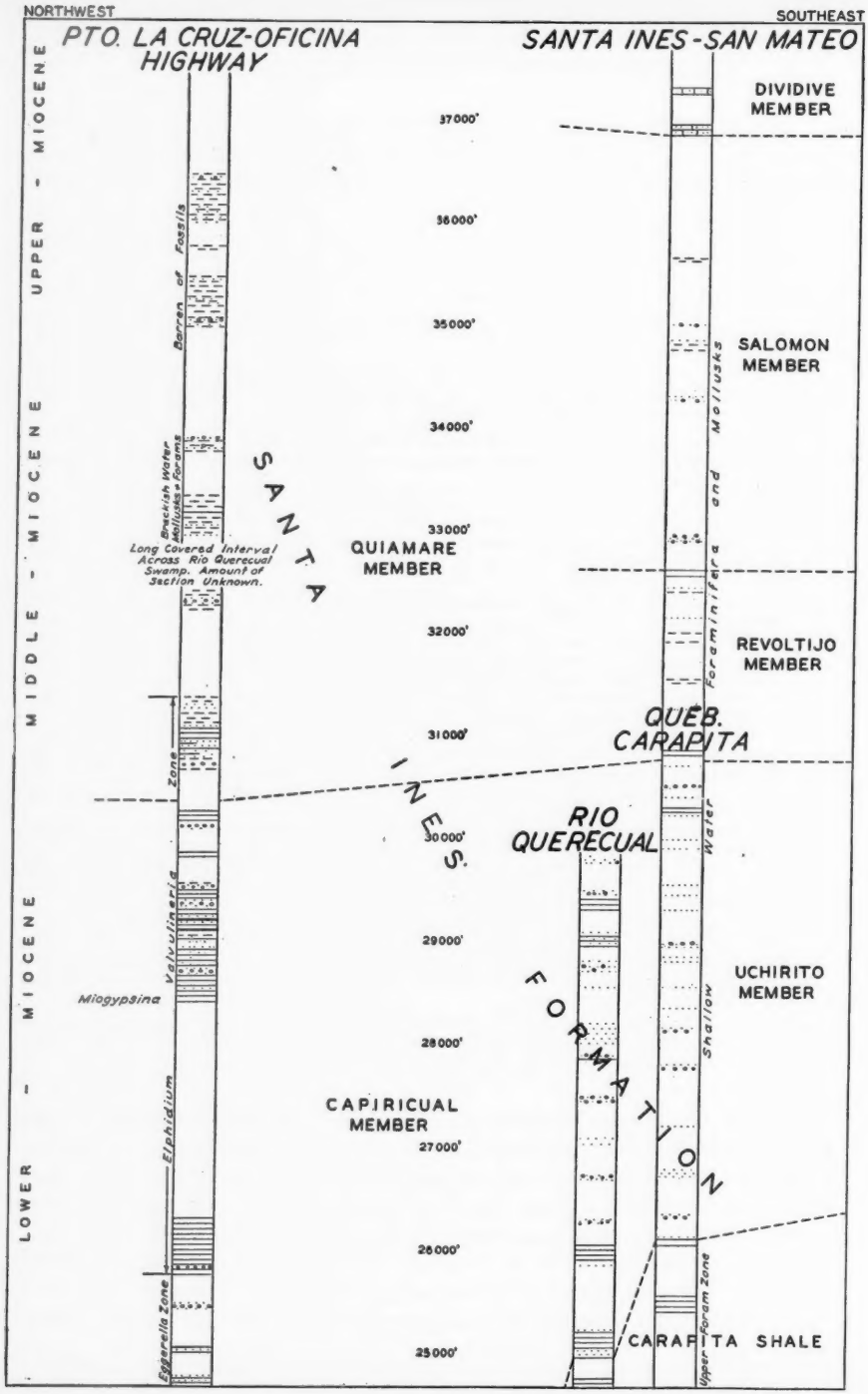


FIG. 4.—Columnar section of northeastern Anzoátegui (upper part).

on Rio Areo appears to indicate, however, that the base of the member is still Eocene.

SANTA INÉS FORMATION (OR GROUP)

(Figures 3 and 4)

The formation was named from the town of Santa Inés in the district of Libertad, state of Anzoátegui. It is essentially a *flysch* formation resulting from the rapid deposition near source of some 24,000 feet of calcareous sandstones, grits, conglomerates, and interbedded shales and claystones, of shallow-water marine or brackish- to fresh-water origin. Exposures in northeastern Anzoátegui show a general gradation from coarser less marine sediments in the west to finer, more shaly, and deeper-water marine sediments in the east.

In the previously published description of the Rio Querecual section the first 9,000 feet of sediments overlying the Merecure formation were assigned to the Carapita formation (7, p. 2004) and the following 15,000 feet to the Santa Inés formation (7, p. 2008). However, it was pointed out that the lower sandstone-bearing part of the Carapita formation bore a close resemblance lithologically to the typical Santa Inés formation and that west of Rio Querecual in the direction of Barcelona the very thick continuous shale section constituting the upper and most distinctive part of the Carapita formation appeared to grade laterally into typical Santa Inés formation (7, p. 2013). Further work has confirmed these points, showing that in the Barcelona area along the Puerto la Cruz-Oficina highway a continuous shale unit comparable to that of the upper part of the type section of the Carapita formation can not be recognized and that its place is taken by sediments essentially similar to the typical Santa Inés formation which thus becomes continuous with the lower sandstone-bearing part of the original Carapita formation and extends downward to the top of the Merecure formation.

Due to this rapid lateral change in facies, a nomenclatural problem has arisen which appears best solved for the present by broadening the scope of the Santa Inés formation to include the original Carapita formation, recognizing the lower sandstone-bearing part of the original Carapita formation as the *Capaya* tongue or member of the enlarged Santa Inés formation, and the thick continuous shale portion of the original Carapita formation as the Carapita shale member of the Santa Inés formation. Other members of the Santa Inés formation are also recognized and it may become desirable to consider the Santa Inés formation as a group rather than a formation and raise the rank of constituent members to formations. This would be particularly justified in the case of the Carapita shale which increases in development and distinctive character eastward.

The type section of the revised Santa Inés formation (or group) extends from a point in Quebrada Carapita about 5 kilometers north of Santa Inés southward along Quebrada Carapita to the Santa Inés road and thence southward across the hills to and including the prominent Cerro Dividive ridges east of San Mateo. The following members (or formations) are recognized in the type section from base to top.

Capaya tongue or member.—This unit coincides with that which was previously described as the lower member of the Carapita formation in Quebrada Carapita (7, p. 2004). It is named from the community of San Antonio de Capaya about 6 kilometers south of Bergantín. It consists of fine-grained laminated gray, greenish gray, brownish-greenish gray, brownish, and pepper-and-salt sandstones and sandy or silty shales with thin seams of clay-ironstone concretions. It is about 2,200 feet thick on Quebrada Carapita, but thickens westward to merge with the Capiricual member of the formation in the Barcelona area.

Carapita shale.—This unit is identical with what was formerly described as the upper shale member of the Carapita formation (7, pp. 2004–08). In the type section on Quebrada Carapita it is almost entirely shale, but it grades westward into the Capiricual member of the formation in the Barcelona area by the development of sandstone and conglomerate beds. In the type section 7,000 feet have been measured, but a part of this thickness may be the result of flowage in the vicinity of the Capaya Z-fold. The Carapita shales are locally highly foraminiferal.

Uchirito member.—This member and the succeeding members of the type section were named by A. Krumholz. The Uchirito member includes the series of ridge-forming chert conglomerates and calcareously cemented sandstones immediately overlying the Carapita shale and forming the topographically prominent Fila de Uchirito. It was previously described as the basal part of the Santa Inés formation (7, p. 2009). It is about 4,500 feet thick on Quebrada Carapita but thickens rapidly westward at the expense of the Carapita shale until it merges with the Capaya tongue to form the Capiricual member in the Barcelona area. The lower part of the member contains intervals of gray fissile foraminiferal shale.

Revoltijo member.—This member is named from Quebrada Revoltijo, a tributary of Rio Aragua south of Santa Inés. It is some 2,000 feet thick and consists dominantly of carbonaceous shales, lignites, and mottled claystones with a minor amount of sandstone and conglomerate. It forms a topographically low belt just south of the Uchirito member outcrop.

Salomón member.—The name is derived from Quebrada Salomón, a tributary of Quebrada Caratas which is in turn a tributary to the Rio Aragua about 8 kilometers southwest of Santa Inés. The member is some 4,200 feet thick and is characterized by dark gray and blue and greenish mottled claystone which weathers to a buff color. There are also hard chert-pebble conglomerates and sandstones which support the rugged topography between the east-west courses of the Querecual and Aragua rivers.

Dividive member.—The uppermost part of the Santa Inés formation consists of some 600 feet of calcareous siltstones, sandstones, and conglomerates which form the Dividive ridge extending from Orijuan to San Mateo.

In the Barcelona area along the Puerto la Cruz-Oficina highway the Santa Ines formation has been divided simply into two members from base to top as follows.

Capiricual member.—The type section of this member is exposed on the Puerto la Cruz-Oficina highway from Kilometer 22 on the north slope of Cerro Grande to the crest of Boca Tigre hill at about Kilometer 36½. It consists of about 12,000 feet of interbedded shales, sandstones, and conglomerates. There are a number of lignites and mottled claystones, largely in the lower part of the member. The sandstones are commonly brownish gray, greenish gray, brownish-greenish gray, and pepper-and-salt color. They are commonly finely laminated. Texture is typically fine- to medium-grained but abruptly defined streaks and lenses of black chert conglomerate occur throughout the whole member and become more common westward. Thicknesses of the sandstone units commonly range from 10 to 30 feet. Probably 80 per cent of the total thickness of the member is gray or brownish gray shale and sandy shale. Seams of clay-ironstone concretions are common. Most of this shale is foraminiferal. The Capiricual member is the lateral equivalent of the combined Capaya, Carapita, and Uchirito members of the Rio Querecual-Quebrada Carapita section.

Quiamare member.—This member is exposed along the Puerto la Cruz-Oficina highway from Kilometer 36½ at the crest of Boca Tigre hill southward to the town of San Mateo. Its thickness is poorly known but probably amounts to 10,000 feet. It consists largely of a series of gray, greenish, red and gray, brown and gray, and blue and gray claystones, with some pebbly sandstones, carbonaceous shales, and lignites. It is largely non-marine although there are two or three thin marine fossiliferous intervals. The Quiamare member is the western equivalent of the Revoltijo, Salomón, and Dividive members of the Santa Inés type section.

There appears to be no unconformity separating the Merecure and Santa Inés formations in the mountain front area of northeastern Anzoátegui, but it is evident that the Santa Inés formation began a new cycle of deposition with a return to at least intermittently marine conditions, with new source rocks, and with renewed activity in sedimentation. Undoubtedly, numerous local unconformities occur in this very thick series of shallow-water marine, brackish-water, and non-marine sediments and it was previously believed that a major unconformity existed in the eastern part of the area between the Carapita shale and the overlying coarse clastics which would now be included in the Uchirito member (7, p. 2012–13). However, it now seems more probable that the angular relation between Carapita sediments and the Uchirito member as noted on Quebrada Carapita, Rio Aragua, and Rio Orégano is of structural origin resulting from the greater deformation of the incompetent Carapita shale as compared with the more competent sandstones and conglomerates of the Uchirito member. Such an explanation would also better fit the facts of regional geology since the supposed unconformity anomalously appeared to die out westward in the direction of less marine and more coarsely clastic sediments.

The Santa Inés formation is in general unconformably overlapped by the Sacacual group of Pliocene sediments. The relation is in many places angular.

The whole of the Santa Inés formation is thus not represented by the outcrop section.

The Santa Inés formation of northeastern Anzoátegui represents a depositional cycle beginning with brackish-water and shallow-water marine deposits at its base, culminating with the moderately deep-water Carapita shales of its middle part and then returning through shallow-water marine, and brackish-water facies to essentially non-marine deposits. The uppermost part of the formation exposed near San Mateo may represent a return to more marine conditions. The Santa Inés formation also shows a general facies change toward increasingly marine conditions from west to east. Even as far west as the Puerto la Cruz-Oficina road, however, brackish-water and shallow-water marine foraminifera are fairly common from the base of the formation through the Capiricual member and for a thousand feet into the Quiamare member. A lower *Eggerella* zone and an upper *Elphidium-Valvulineria* zone have been provisionally recognized in this foraminiferal section. Eastward from the highway section the change in depositional facies is reflected in a rapid change in foraminiferal facies with the coming in of much more varied faunas. Thus the lower, middle, and upper foraminiferal zones of the Carapita member on Quebrada Carapita (8) do not correspond with the zones which would be set up on the Capiricual or highway sections.

Molluscan fossils are fairly common throughout the whole formation, except in the deeper-water Carapita shales, and numerous collections have been made which have not yet been thoroughly studied. Fossil occurrences of particular note with respect to the age of the Santa Inés formation are as follows.

1. A collection of mollusks from near Mesones south of Barcelona about 2,500 feet above the base of the Santa Inés formation was sent to Julia Gardner who besides other forms identified *Psammosolen* sp. ("a rather rare and exceptionally well characterized genus in the Oligocene and Lower Miocene of the Gulf province; so far as I know it has not been recorded before the Oligocene in the Gulf") and three species of *Turritella* "belonging to groups well represented in the Oligocene and Miocene."
2. In a collection from the Puerto la Cruz-Oficina highway section in the Capiricual member about 7,000 feet above the base of the formation Miss Gardner identified *Chione* (*Chione*) sp. indicating "an age not earlier than late Oligocene."
3. Analysis of the assemblage of small foraminifera in the middle zone of the Carapita shale on Quebrada Carapita indicates late Oligocene age (8)
4. Mollusks from the Uchirito member on Quebrada Carapita and Rio Querecual suggest middle Miocene age (7, pp. 2,011–12).
5. *Miogypsina* sp. in shales about 2,000 feet below the top of the Capiricual member on the Puerto la Cruz-Oficina Highway suggest an age not younger than early Miocene.

In review, it appears certain that the Santa Inés formation includes sediments from middle Oligocene to middle Miocene in age. It may include some part of the lower Oligocene and some part of the upper Miocene.

SACACUAL GROUP

Unconformably overlapping the Santa Inés and older formations about the southern border of the northeastern Anzoátegui mountain front and extending far southward to the Orinoco River, is a series of non-marine claystones, silt-

stones, sandstones, and some pebbly beds which comprise the Sacacual group and which may attain a thickness of several thousand feet. The name is derived from Quebrada Sacacual which cuts through these beds south of San Mateo. The sediments of this group show considerable lateral variation and unconformities of considerable magnitude are developed within it. Facies differences have furnished the basis for recognition of several different formations within the group but discussion of these will be deferred. The Sacacual group is probably approximately Pliocene in age although there is little on which to base this assignment except the unconformable relation to upper Miocene sediments of the upper Santa Inés and the presence of a few brackish-water fossils. This group appears to grade eastward into more marine sediments.

MESA FORMATION

The youngest stratigraphic unit of northeastern Anzoátegui is the Mesa formation. This formation is widespread over the Eastern Venezuelan basin, constituting the cap rock of the broad mesa which form such a striking physiographic feature of this region. The sediments of this formation are apparently of diverse origin. Near the mountain front they consist dominantly of several hundred feet of pebble, cobble, and even boulder gravels and evidently represent a series of coalescing alluvial fans formed during rapid erosion of the Cretaceous and Tertiary rocks of the Serranía and deposited across the eroded edges of all older formations. The formation thins southward to 50–100 feet in the interior plains and decreases in grade size. Here it evidently also includes locally reworked stream gravels, eolian deposits, and residual deposits, and its relation to the underlying Sacacual group varies locally from distinct erosional unconformity to apparent transition.

Fossils in the Mesa formation are largely limited to local occurrences of petrified wood. The formation is commonly considered of Pleistocene age but without any very definite basis. Certainly it is older than the last major uplift of the mountains as it shows gentle tilting and warping and is also locally faulted. Only eroded remnants such as Cerro Corozal remain in the foothills areas and these are definitely much older than the alluvium of the present rivers, which have cut several hundred feet below the base of the Mesa beds.

REGIONAL BACKGROUND FOR STRATIGRAPHY OF NORTHEASTERN ANZOÁTEGUI

Northeastern Anzoátegui is a part of the general eastern Venezuelan depositional basin or geosyncline. This geosyncline was bounded on the south by the relatively stable Guayana shield and on the north by the actively southward thrusting borderland of Paria. Communication with the open ocean has been largely on the east. As a result of southward pressure of the Parian borderland and consequent buckling of the northern border of the sedimentary trough, the axis of the geosyncline has been repeatedly shifted southward (7, pp. 2013–21). In the central part of this southward-shifting basin, deposition has been essentially

continuous throughout Cretaceous and Tertiary time. Along its northern edge active erosion has accompanied successive orogenic movements of the Paria borderland with the resultant formation of angular unconformities. Along the stable southern side on the border of the Guayana shield marked angular divergences of strata are largely lacking, though hiatuses, erosional unconformities, and overlaps have resulted from epeirogenic movements.

Until Oligocene time northeastern Anzoátegui lay to the south of the geosynclinal axis and on the slope of the Guayana shield. During Carapita shale deposition (upper Oligocene) it was probably in the axial part of the basin. Only after Oligocene time had the axis of the geosyncline been shifted far enough toward the south so that northeastern Anzoátegui actually lay north of this axis. Thus only in the younger sediments, formed after the area had become a part of the mobile borderland of Paria, are angular unconformities found—Santa Inés-Sacacual unconformity, Sacacual-Mesa unconformity. The older and major part of the section in northeastern Anzoátegui constitutes an essentially conformable nearly continuous series. At no time during the period from Lower Cretaceous to middle Miocene time was there sufficient disturbance in this area to create any strong angular relation between any of the several formations or sufficient erosion to change the sequence of formations or even to markedly reduce the thickness of individual formations in this regular sequence.

The great transgression which began in early Cretaceous time left a fairly continuous record of the period in northeastern Anzoátegui though there may be some stratigraphically condensed intervals and minor hiatuses in the section there. Toward the close of the Cretaceous there was a general tendency toward emergence or shallowing of the sea and a retreat from the borders of the Guayana shield. As a result, both of this regression and of subsequent mild erosion on the borders of the shield, the younger Cretaceous formations are probably successively more limited in southern extent at the present time. The climax of this epeirogenic movement appears to have been reached in northeastern Anzoátegui not exactly at the Cretaceous-Tertiary boundary but somewhat later, within the Eocene period toward the close of Santa Anita formation deposition. At this time actual emergence and erosion may have occurred in the vicinity of Barcelona (Santa Anita-Merecure unconformity) though there is little or no evidence of angular unconformity. Sedimentation appears to have been continuous in the eastern part of the area across this formational contact. Farther north at the northern edge of the geosyncline, crustal movements were more intense and here there may have been orogenic episodes both at the close of the Cretaceous and at the close of Santa Anita deposition.

In late Eocene time the sea became somewhat more widespread (marine deposits of the lower Merecure formation). The initial marine phase did not persist in northeastern Anzoátegui however and was replaced by coal-basin sedimentation which probably continued into early Oligocene time. In middle

Oligocene time, with the northeastern Anzoátegui area near the axis of the geosyncline, a major marine transgression began. During this cycle the flysch-like Santa Inés formation was deposited in northeastern Anzoátegui and the limits of the epicontinental sea farther south extended well beyond those of Merecure deposits. The deep-water facies of the Carapita shale was probably deposited while northeastern Anzoátegui occupied a position along the axis of the geosyncline. When the Santa Inés cycle terminated near the close of the Miocene, northeastern Anzoátegui had already become a part of the mobile belt of Paria north of the axis of the sedimentary basin and its sediments were therefore strongly folded before they were covered by the Sacacual group with angular unconformity.[4] Similarly, later in the Pliocene the Sacacual sediments were deformed by a further orogeny before Mesa deposition. Both the Santa Inés-Sacacual and Sacacual-Mesa angular unconformities die out southward toward the axial position of the late Tertiary geosyncline and in both cases the younger formation overlaps the older to the south.

As a result of the conditions outlined, a well drilled near the southern border of the Eastern Venezuelan basin might, for example, pass directly from middle Miocene into Lower Cretaceous sediments with the time value of the hiatus equal to Upper Cretaceous, Paleocene, Eocene, Oligocene, and early Miocene time. A little farther north, a well might pass from upper Merecure (lower Oligocene) into San Antonio (Upper Cretaceous) with the hiatus equal to Paleocene and Eocene time. Still farther north, the well section might show lower Merecure (upper Eocene) resting on middle Santa Anita (Paleocene) with lower and middle Eocene missing. Finally a section in the eastern part of the northeastern Anzoátegui area might show a continuous sequence of formations with even lower and middle Eocene represented by upper Santa Anita deposits and a transition zone between Santa Anita and Merecure formations.

REFERENCES

1. COLLET, L. W., "Sur la Presence au Venezuela d'Aptien a faune Mediterraneo-Alpine," *Compt. Rend. Soc. Phys. Hist. Nat. Geneve*, Vol. 39, No. 1 (1922), pp. 16–17.
2. COOKE, C. W., "Oligopygus Nancei, a New Echinoid from Venezuela," *Jour. Pal.*, Vol. 15 (1941), pp. 305–06.
3. CUSHMAN, J. A., AND HEDBERG, H. D., "Upper Cretaceous Foraminifera from Santander del Norte, Colombia, S. A.," *Contr. Cushman Lab. Foram. Res.*, Vol. 17, Pt. 4 (1941).
4. DE JUANA, C. GONZALES, AND AGUERREVERE, S. E., "Informe Geológico de Parte de los Depósitos de Carbón del Rio Naricual," *Bol. Geol. Min.* (Caracas), Vol. 2, No. 1 (1938), pp. 5–32.
5. GREGORY, J. W., "Some Lower Cretaceous Corals from Eastern Venezuela," *Geol. Mag.*, Vol. 64 (1927), pp. 440–44.
6. HARRIS, G. D., AND HODSON, F., "The Rudistids of Trinidad," *Paleontographica Americana*, Vol. 1 (1922).
7. HEDBERG, H. D., "Stratigraphy of the Rio Querecual Section of Northeastern Venezuela," *Bull. Geol. Soc. America*, Vol. 48 (1937), pp. 1971–2024.

[4] There is some evidence from well sections in central Anzoátegui to indicate that another marine transgression and depositional cycle, represented either in part by the uppermost Santa Inés of the San Mateo area or by still younger sediments now overlapped by the Sacacual group, may have intervened between the principal Santa Inés cycle and Sacacual deposition.

8. ———, "Foraminifera of the Middle Tertiary Carapita Formation of Northeastern Venezuela," *Jour. Pal.*, Vol. 11, No. 8 (1937), pp. 661–97.
9. ———, "Mesozoic Stratigraphy of Northern South America," *Proc. 8th Amer. Sci. Congress* (1942), pp. 195–227.
10. HEINZ, R. "Uber die Oberkreide-Inoceramen Sud-Amerikas und ihre Beziehungen zu denen Europas und anderer Gebiete," *Mitt. Min.-Geol. Staatsinst. Hamburg*, Vol. 10 (1928), pp. 41–97.
11. LIDDLE, R. A., *The Geology of Venezuela and Trinidad*. J. P. Macgowan, Fort Worth, Texas (1928).
12. RENZ, H. H., "Stratigraphy of Northern South America, Trinidad, Barbados," *Proc. 8th Amer. Sci. Congress* (1942), pp. 513–71.
13. RUTSCH R. "Beitrage zur Kenntnis tropisch-amerikanischer Tertiar-mollusken. IV. Die Stratigraphische Bedeutung der Venericardia Planicosta und ihrer Verwandten. V. Ist Venericardia Beaumonti auf die Oberkreide beschrankt?" *Eclog. Geol. Helv.*, Vol. 29, No. 1 (1936), pp. 151–207.
14. ———, "Terebratulina Kugleri, N. Sp. from the Eocene of Soldado Rock," *Jour. Pal.*, Vol. 13, No. 5 (1939), pp. 517–20.
15. ———, "Die Gattung Tubulostium im Eocaen der Antillen," *Eclog. Geol. Helv.*, Vol. 32, No. 2 (1939), pp. 231–44.
16. SENN, A., "Paleogene of Barbados and its Bearing on History and Structure of Antillean-Caribbean Region," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24, No. 9 (1940), pp. 1548–1610.
17. SPATH, L. F., "Tithonian Ammonites from Trinidad," *Geol. Mag.*, Vol. 76, No. 898 (1939), pp. 187–89.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 1 (JANUARY, 1944), PP. 29-62, 15 FIGS.

GENERAL GEOLOGY OF MISSISSIPPI[1]

TOM McGLOTHLIN[2]
Jackson, Mississippi

ABSTRACT

The stratigraphy of formations in Mississippi, ranging in age from the top of the Paleozoic to the Recent, is briefly described in this paper.

INTRODUCTION

This paper is limited to a generalized description of the post-Paleozoic stratigraphy of Mississippi with a few notes on the regional structure.

Acknowledgments are here given to: the officials of the Gulf Oil Corporation for permission to publish the paper; the late Arthur Wedel for his paleontological determinations, and for his helpful discussions on the many problems in the stratigraphy of Mississippi; to Roy T. Hazzard and B. W. Blanpied, Gulf Refining Company, for helpful suggestions and criticisms; to John D. Moody, Gulf Refining Company, who, with the writer, during 1940, studied well cuttings and compiled cross sections in Mississippi; to John Berg, Pure Oil Company; and Lloyd Parker, Texas Pacific Coal and Oil Company, for helpful discussions.

GENERAL STATEMENTS

The structure map of Mississippi (Fig. 1), contoured on the base of the Porters Creek clay of the Midway group, with a contour interval of 200 feet, shows the larger structural features. They include: (1) the Sharkey platform, a part of the eastern flank of an unnamed major subsurface structural feature which underlies part of West Carroll and Morehouse parishes, Louisiana, and an adjacent part of Arkansas; (2) the Jackson dome; and (3) the Wiggins anticline. The regional southwest-dipping monoclinal structure of the greater part of Mississippi, which is interrupted by the structural features here listed, is noteworthy. The structural depression between the Sharkey platform and the Jackson dome is here named the Big Black River syncline.

The smaller features are: Tinsley, Pickens, Kilmichael, Morton, and Quitman. The known salt domes are: Edwards, Newman, Glass, Midway, Tatums, Kings, Halifax, and D'Lo.

Cross section *AA'* (Fig. 3) extends from Issaquena County to Scott County, crossing the Big Black River syncline and the Jackson dome. On the flank of the Sharkey platform, the Trinity, the Tuscaloosa, the Eutaw, and that part of the Selma which is Taylor in age, have been truncated and are overlapped locally (in the area between the Reid Clarke Allen well No. 1 in Humphreys County, and the Eureka's Cooper well No. 1 in northern Sharkey County) by Selma chalk of Navarro age, and overlapped regionally by the Monroe gas rock of Navarro age.

[1] Read before the Association at Houston, April, 1941. Manuscript received, May 10, 1943.

[2] Geologist, Gulf Refining Company, Gulf Production Division.

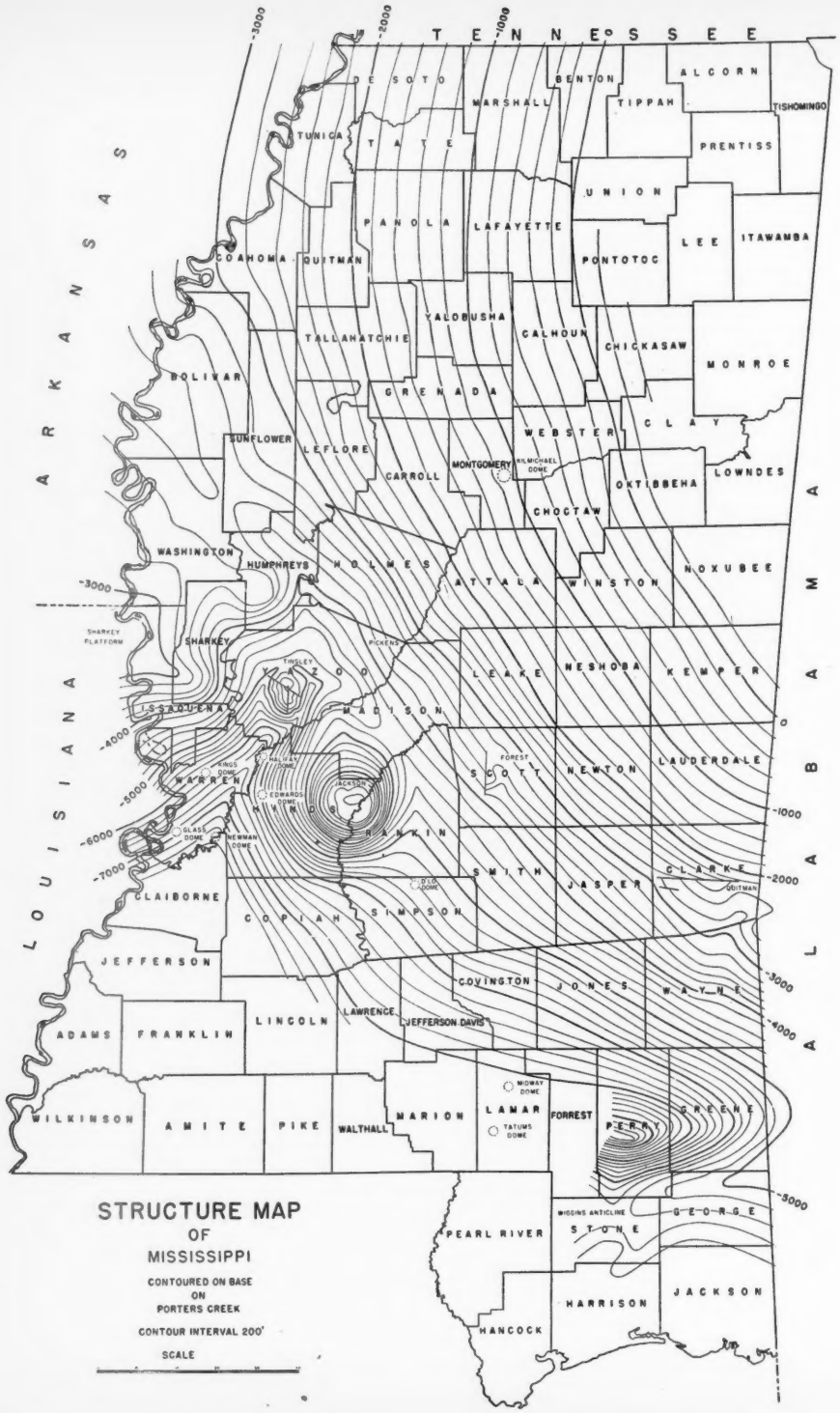


FIG. 1.—Structure map of Mississippi, contoured on base of Porters Creek clay. Contour interval, 200 feet.

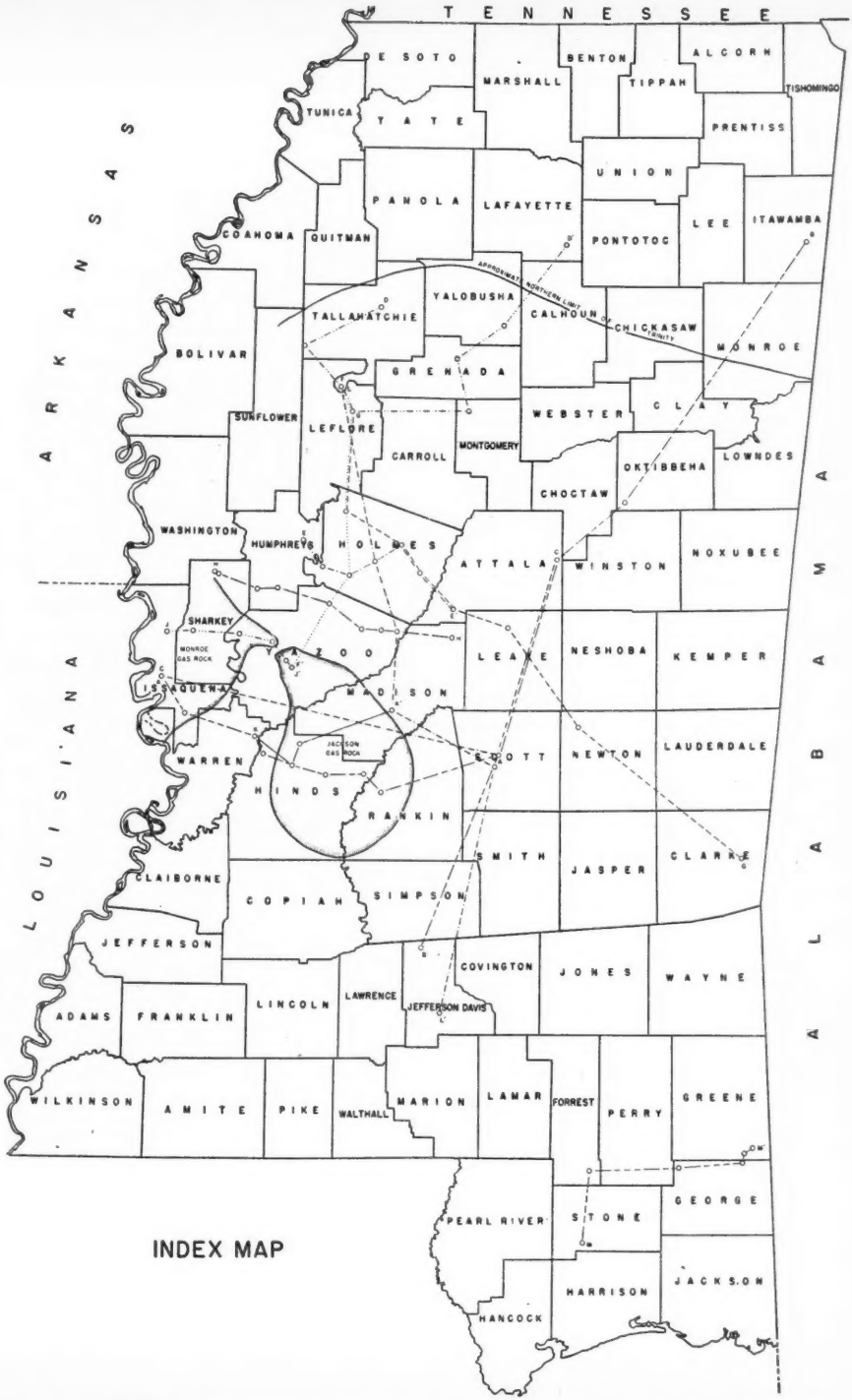


FIG. 2.—Index map showing location of sections, and areas underlain by Jackson and Monroe gas rock.

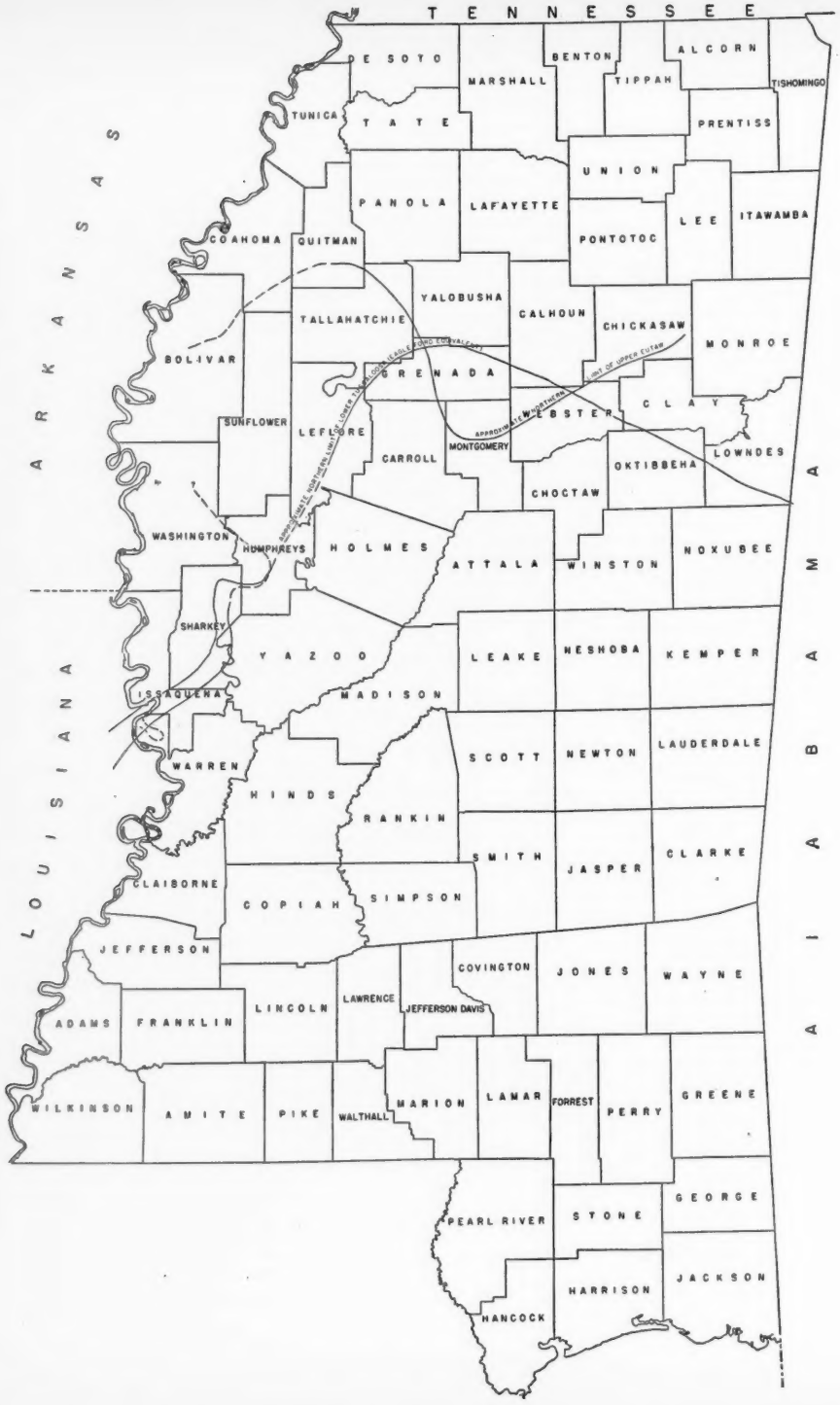


FIG. 2A.—Present approximate limits of lower Tuscaloosa and upper Eutaw.

This overlapping is in a westerly direction. Over the top of the Jackson dome, the Trinity, the Tuscaloosa, the Eutaw, and the Taylor have been truncated and are overlapped by the Jackson gas rock, which is mainly Navarro in age.

The shaded areas on the index map (Fig. 2) indicate the approximate extent of the areas underlain by the Jackson and the Monroe gas rocks. The two may or may not connect northwest of the Tinsley field.

In general throughout Mississippi, structural maps contoured on the top of the Wilcox, the base of the Porters Creek, and the top of the Eutaw show similarity of pattern and degree of deformation. Structural maps of the area underlain by the Jackson gas rock show this similarity between the top of the Wilcox and the top of the Eutaw, but not the base of the Porters Creek. This is due to the variable thickness of the Jackson gas rock, and to the consequent localized thinning of the Porters Creek clay which overlies it. The map contoured on the base of the Porters Creek, in the Jackson gas rock area, shows the relief of the underlying reef-like lithologic unit rather than true structure.

The line from Bolivar County to Noxubee County, on the index map, indicates the approximate northern limit of the Trinity. The approximate northern limits of the upper Eutaw and lower Tuscaloosa are shown in Figure 2-A.

Formations that crop out, or that have been encountered in wells in Mississippi, range in age from the Ordovician to the Recent. Figure 4 is a northeast-southwest cross section through eastern Mississippi, showing the general relationship of beds from the Ordovician to the lower Miocene.

Mesozoic Era—Jurassic System

Weeks[3] and Imlay[4] have discussed the pre-Comanche beds which underlie North Louisiana and South Arkansas, and more recently Imlay[5] has described their fauna and correlations with the Jurassic of northern Mexico and Europe. In this paper the Jurassic nomenclature in current use by geologists in North Louisiana and South Arkansas is being followed.

Conclusive data pertaining to post-Paleozoic and pre-Comanche formations are meager. It is probable that the Eagle Mills formation is the source of the salt found in the salt domes of Mississippi. The formation does not crop out, nor has it been recognized in wells. The Smackover and Buckner, or their equivalents, are not known in Mississippi but probably underlie the south half of the state. The Union Producing Company's Waite well No. 1, Clarke County, Alabama, reached the Eagle Mills formation. Rock salt was encountered below a limestone and anhydrite section of Smackover age.

[3] Warren B. Weeks, "South Arkansas Stratigraphy with Emphasis on the Older Coastal Plain Beds," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 22, No. 8 (August, 1938), pp. 953–83.

[4] Ralph W. Imlay, "Lower Cretaceous and Jurassic Formations of Southern Arkansas," *Arkansas Geol. Survey Inform. Cir. 12* (1940).

[5] *Idem*, "Jurassic Fossils from Arkansas, Louisiana, and Eastern Texas," *Jour. Paleon.*, Vol. 15, No. 3 (1941).

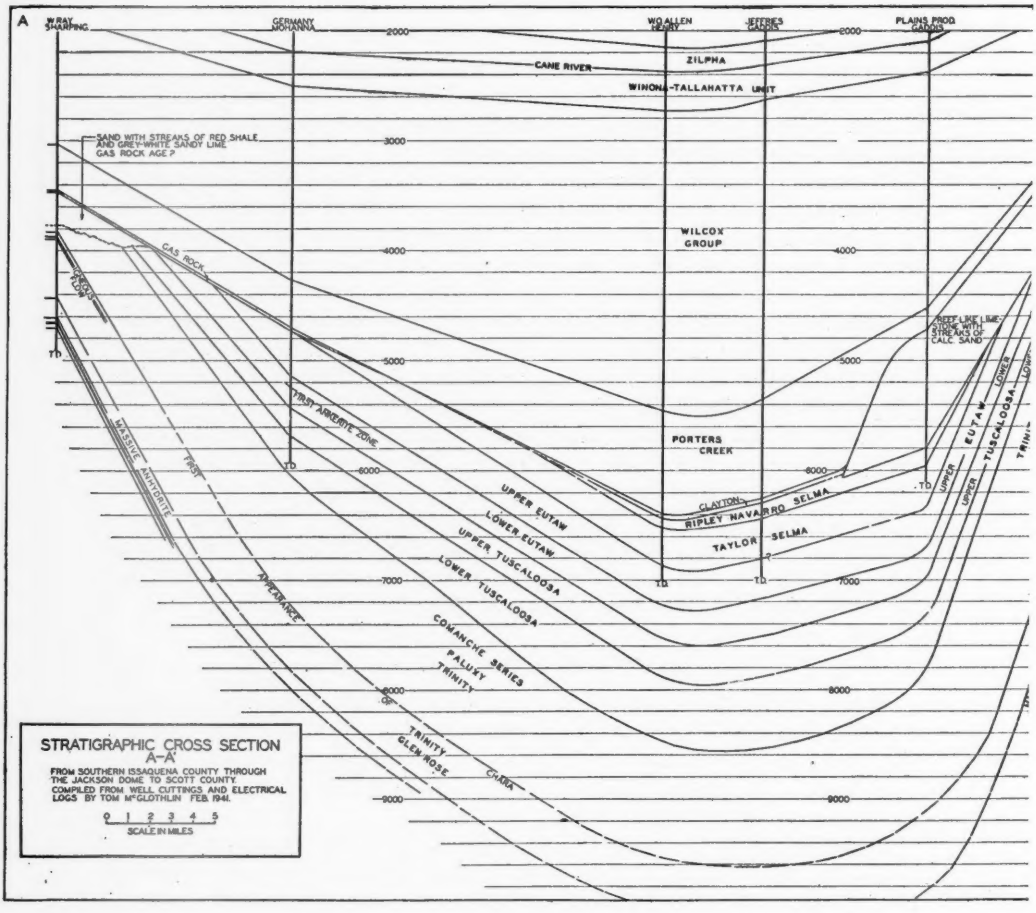
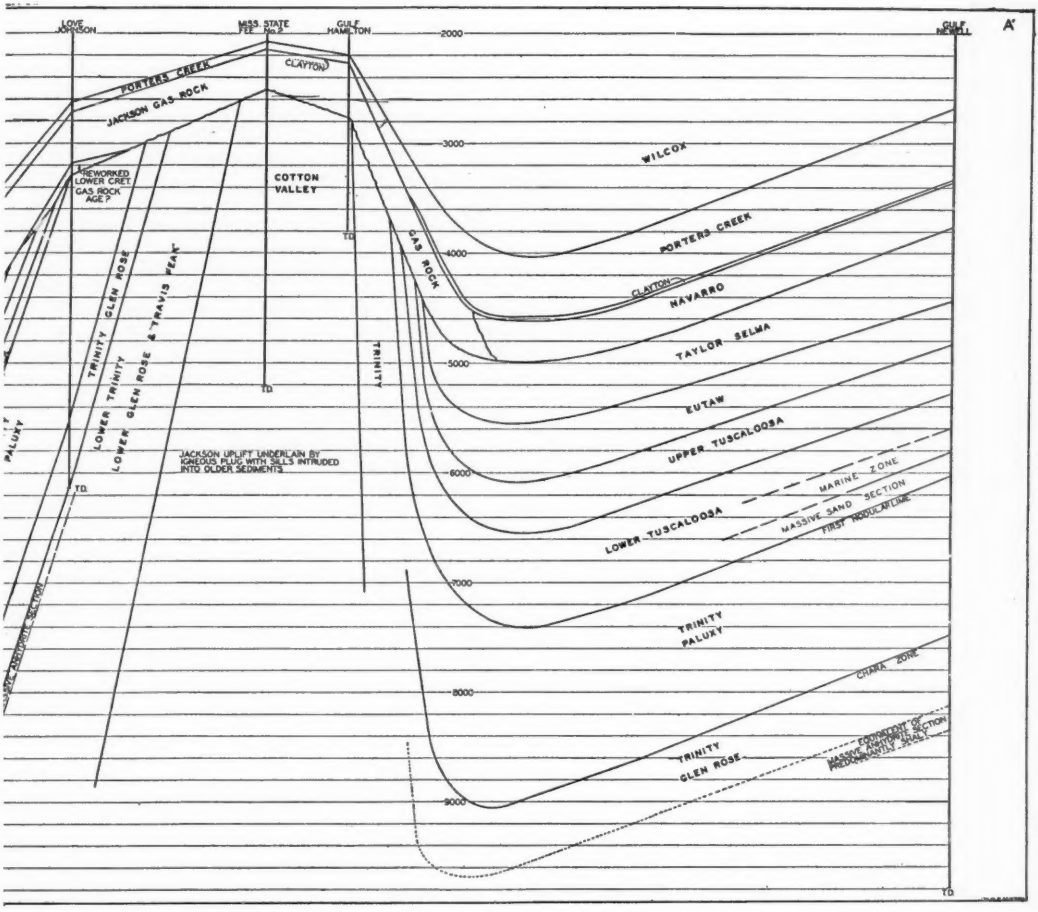


FIG. 3.—Section *AA'*, from

Cotton Valley formation.—Approximately 2,700 feet of strata believed to be the Schuler facies of the Cotton Valley formation were encountered in the Mississippi State Fee well No. 2, just north of the top of the Jackson dome. The thickness of the Cotton Valley can not be estimated accurately because the entire section was not penetrated, and the section encountered had high-angle dips. The formation consists of red shales, and variegated red and gray waxy or talcous shales interbedded with fine- and medium-grained sands. Associated with some of the waxy shales are small round, brown or red pellets of siderite or ankerite. No fossiliferous material was observed in the well cuttings. In the Union Produc-



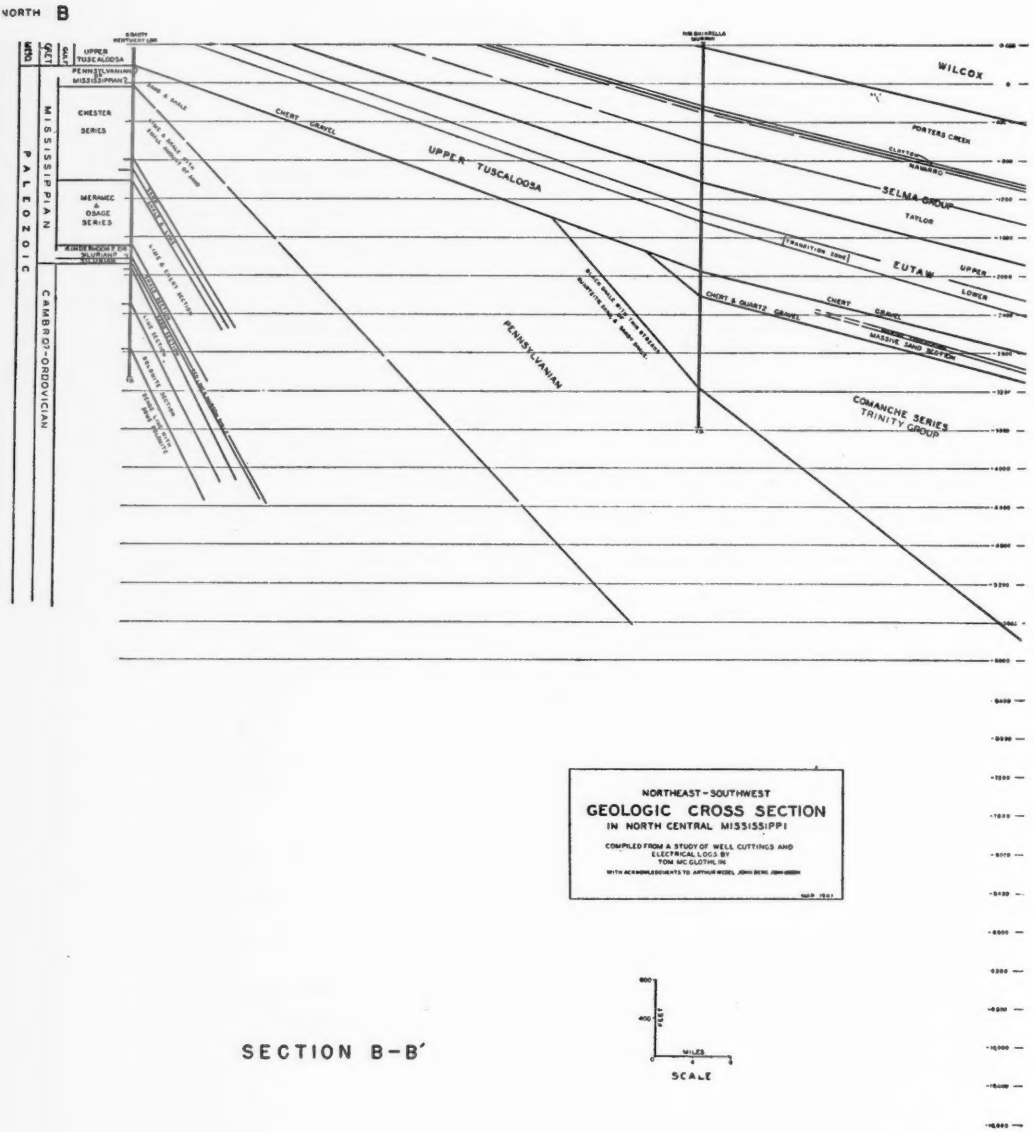
Issaquena County to Scott County.

ing Company's Waite No. 1, Clarke County, Alabama, the probable equivalent of the Cotton Valley is represented by approximately 2,400 feet of gravels, sands, and gray, purple-red, and red talcous shales.

Cretaceous System

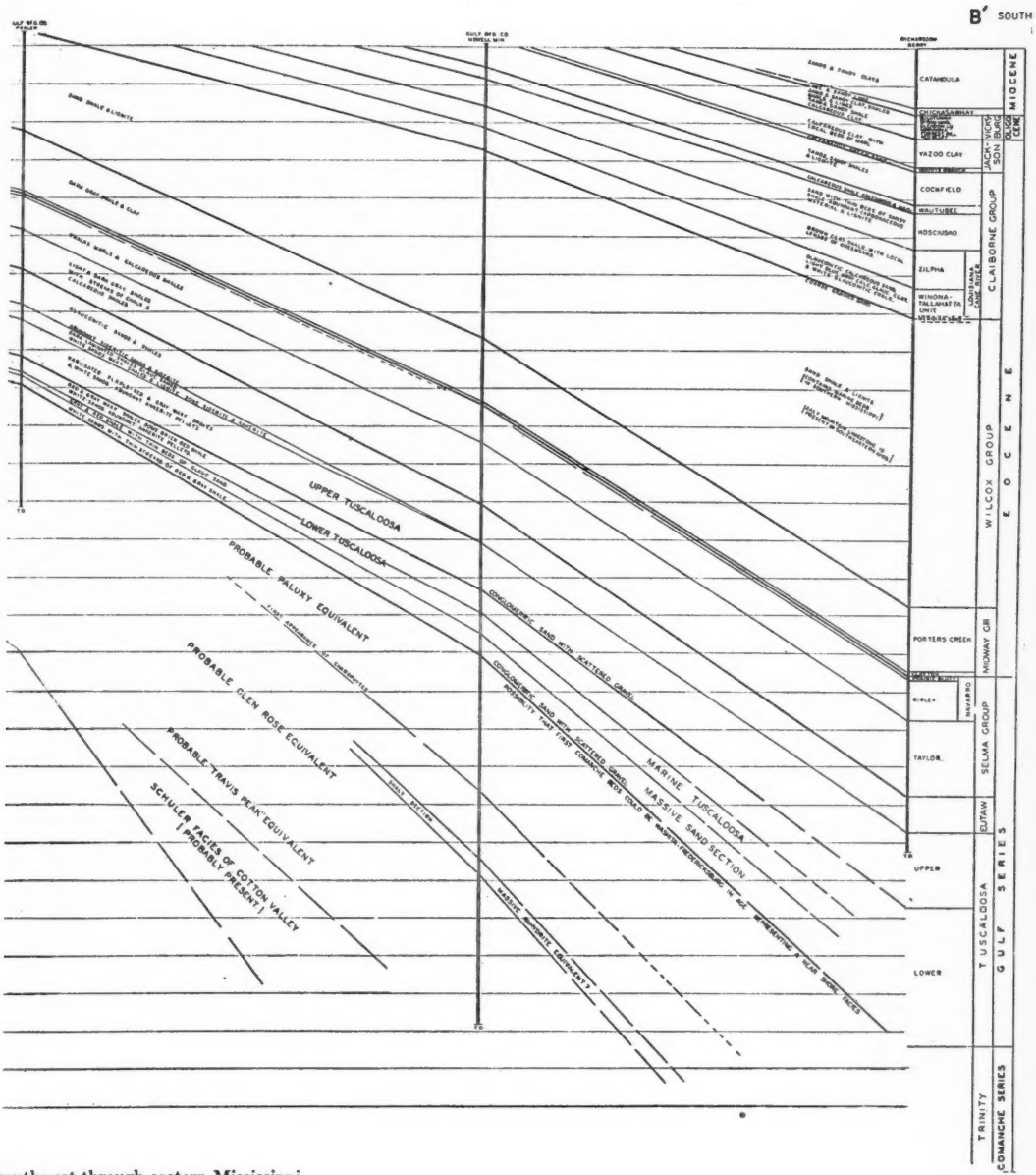
Comanche Series

The Comanche series is represented in Mississippi by the Trinity group. Beds of probable Hosston ("Travis Peak") age are included in the Trinity group in this paper. Beds of Washita and Fredericksburg age may be present in the ex-

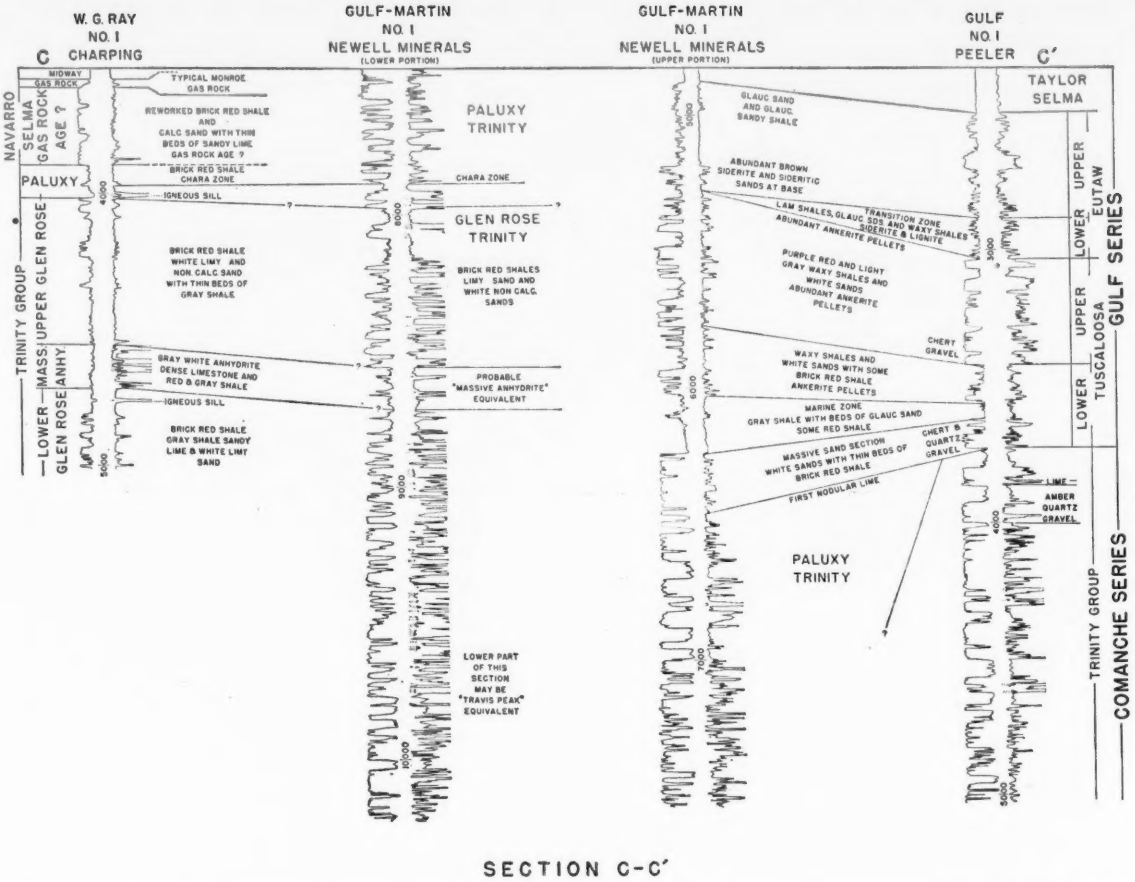


SECTION B–B′

FIG. 4.—Section *BB′*, northeast and



southwest through eastern Mississippi.



SECTION C-C'

FIG. 5.—Section *CC'*. Electrical log correlation. Upper part of Gulf-Martin's Newell Minerals log is correlated with Gulf's Peeler. Lower part Gulf-Martin well is correlated with Ray's Charping. Compiled from study of well cuttings and cores.

treme southwest part of the state. It is possible but not probable that some of the highest Lower Cretaceous material that is being called Trinity is a nearshore facies of the Washita-Fredericksburg.

Figure 5 is an electrical-log correlation section, showing the relationships between the Trinity and the overlying formations. This section was compiled from a detailed sample study. On the west side of the Big Black River syncline in Issaquena County, Ray and Wolfe's Charping No. 1 encountered approximately 1,765 feet of Paluxy and Glen Rose beds. The well stopped in lower Glen Rose, but as apparently nearly all of the Paluxy is truncated, the thickness of the Trinity group can only be estimated. The Glen Rose "Massive anhydrite" is represented in this well by approximately 180 feet of white and grayish white finely crystalline anhydrite interbedded with dark gray shale, and dense limestone. The percentage of anhydrite decreases eastward from this well, only a trace occurring in cuttings in Cleve Love's Johnson No. 1, Hinds County, and none in the Gulf-Martin's Newell Minerals No. 1, Scott County. The predominantly shaly zone from 8,580 to 8,810 feet in the Gulf-Martin well is probably the time equivalent of the "Massive anhydrite."

Spores of calcareous algae, charophytes, have been noted in many wells in Mississippi,[6] the highest appearing approximately 580 feet above the anhydrite in the Charping well, and 600 feet above the anhydrite in the Cleve Love's Johnson No. 1. They have been noted in wells farther east where anhydrite is not present. It is believed that the highest appearance of the charophytes is in the basal part of the Paluxy.

The presence of charophytes in the Trinity of North Louisiana and South Arkansas has been noted by several paleontologists. Of interest is the record of a charophyte zone in the Gulf Refining Company's Sondheimer No. 1, Sec. 33, T. 18 N., R. 12 E., Madison Parish, Louisiana. This zone occurs at the depth of 3,900–3,920 feet, approximately 650 feet above the top of the "Massive anhydrite." The writer is indebted to the late Arthur Wedel and to John Berg, of the Pure Oil Company, for specific information concerning this charophyte zone. As far as the writer knows, Wedel and Berg were the first to note and study the occurrence of charophytes in Mississippi, and to assign some stratigraphic value to them. The writer concurs with their viewpoint.

E. B. Hutson, of the Carter Oil Company, has noted the occurrence of several distinct species of charophytes in the Gulf-Martin's Newell Minerals No. 1, Scott County. There may be several zones of charophytes in the Trinity of Mississippi, in addition to the widespread zone noted by Wedel and Berg.

It is perhaps too early in the study of the stratigraphy of Mississippi to subdivide the Trinity group with certainty. West of the Big Black River syncline the Trinity section is similar to that of Louisiana, but east of the syncline it is very difficult with the present limited data to give formational rank to any se-

[6] Study Group Project of the Mississippi Geological Society on Subsurface Sections of Central Mississippi (1941).

quence of beds. The Trinity group consists mainly of brick-red shales, some of which contain pink nodular limestone, sandstones, calcareous sandstones, and thin beds of sandy limestone. In Montgomery and Attala counties, a bed of fine amber-colored quartz gravel, having a thickness of approximately 50 feet, lies about 150 feet below the highest Trinity. The top of the Trinity is usually recognized lithologically by the first appearance of brick-red shales containing pink and grayish white nodular limestone. It is the writer's opinion that the basal Gulf Cretaceous rests unconformably on the Trinity. The greatest thickness of the Trinity recorded in Mississippi is approximately 3,800 feet in the Gulf-Martin well in Scott County. It thins north and northeast and is overlapped by the upper Tuscaloosa.

GULF SERIES

"Tuscaloosa formation."—In the writer's opinion, the series of beds that is now called the "Tuscaloosa formation" can be subdivided into two formations. In this paper these beds are referred to as the lower Tuscaloosa and the upper Tuscaloosa. There appears to be a major unconformity between the two, with the lower wedging-out updip and being overlapped by the upper. It would probably be logical to restrict the term "Tuscaloosa" to those beds that are assigned here to the upper Tuscaloosa, and to give a new name to the lower beds, but the writer hesitates to give new names to formations where a political boundary is crossed.

Lower Tuscaloosa.—The lower Tuscaloosa can be roughly divided into three divisions, from oldest to youngest: the "Massive sand section," the "Marine section," and the shale and sand section.

The "Massive sand section" is a series of medium- to coarse-grained sands ranging in thickness from approximately 100 feet in Attala County southward to 300 feet in the Wiggins anticline area of southern Forrest County, and thinning westward from this maximum thickness. Probable equivalent sands in the Tide Water Associated Oil Company's Denkmann Lumber Company No. 1, Lawrence County, Mississippi, have a thickness of approximately 45 feet. In wells in Concordia and Catahoula parishes, Louisiana, the "Massive sand" equivalent has a thickness of 30–50 feet. Gas and distillate were encountered in this zone in The California Company's Pan-American Life Insurance Company No. 1, Concordia Parish, Louisiana. Beds of mottled red and gray waxy, ankeritic shale and some beds of brick-red shale occur immediately above, and within the "Massive sand" section. In Attala, Leake, Newton, and Lauderdale counties, and northward, a 20-foot bed of chert and quartz gravel lies at the base of the "Massive sand," but southward this gravel grades into conglomeratic sands with scattered pebbles. In these counties, the basal gravel of the "Massive sand section" rests on Trinity beds characterized by pink and gray-white nodular limestone. In the Fohs Oil Company's Batson-Hatton No. 1, Forrest County, Mississippi, a gravelly sand at the base of the "Massive sand" rests on brick-red shale with nodular limestone of probable Paluxy age.

The "Marine section" consists of dark gray shale and chloritic (?) and glauconitic sands, ranging in thickness from 50 to 290 feet, and containing fossils that have been determined to be Eagle Ford in age.[7,8,9,10] Toward the north, the "Marine section" contains some beds of brick-red shale.

In Yazoo, Madison, Attala, Leake, Neshoba, Scott, and Newton counties, the upper division of the lower Tuscaloosa is a sequence of red-brown, purple-red and gray waxy or talcous shales, some brick-red shale interbedded with sands, and subordinate amounts of dark gray shale. Abundant brown and red ankerite pellets, having the size of coarse sand grains, occur in the waxy shales. The upper division of the lower Tuscaloosa has a thickness range from 140 feet at the north to 380 feet toward the southeast. Toward the south and southeast, it becomes more marine as the percentage of dark gray shale increases, and in southern Forrest and Stone counties it consists of dark gray shale. The Magnolia Petroleum Company's Culpepper No. 1, Lauderdale County, encountered dark gray shales at the very top of the lower Tuscaloosa.

Upper Tuscaloosa.—Northward from Lauderdale, Newton, Leake, Attala, and Holmes counties, a bed of yellow-white and white chert gravel, having a thickness between 50 and 100 feet, rests successively on the lower Tuscaloosa, the Trinity, and Paleozoic beds. In Lafayette County it rests on the Pottsville, in Tallahatchie, LeFlore, and Grenada counties it rests on the Trinity, and downdip in other parts of the state it rests on the lower Tuscaloosa. Toward the south and southeast, this gravel zone grades into conglomeratic sands containing scattered pebbles. The upper Tuscaloosa beds overlying the basal gravel consist of approximately 100–450 feet of gray waxy shales; mottled purple-red and gray waxy shales, sands, and sands containing scattered pebbles; many large ankerite pellets associated with both the sands and waxy shales.The top of the upper Tuscaloosa is arbitrarily determined by the highest appearance in abundance of large ankerite pellets. The upper Tuscaloosa grades into the overlying Eutaw. Locally updip near the outcrop, a bed of basal Eutaw gravel rests on upper Tuscaloosa. The upper Tuscaloosa in Mississippi is limited on the northeast by its outcrop but underlies the balance of the state except where it has been truncated on the flank of the Sharkey platform and over the Jackson dome, and where it has been pierced by salt domes. Near the source of its sediments on the north and northeast it contains more gravel. In Stone, Greene, and George counties the beds of the upper Tuscaloosa contain an abundance of dark gray marine shales.

Eutaw formation.—The Eutaw is limited on the northeast by its outcrop, and, like the Tuscaloosa, is truncated on the flank of the Sharkey platform and over

[7] Arthur Wedel, personal communication (1940) on occurrence of *Cytheropteron eximum* in Lion Oil Refining Company's Misterfelt No. 1, Rankin County, Mississippi.

[8] Marcus A. Hanna, personal communication and unpublished reports.

[9] Gayle Scott, personal communication with Roy T. Hazzard on occurrence of *Metoicoceras* sp.

[10] L. W. Stephenson, letter of February 8, 1934, to Swearingen on occurrence of *Inoceramus fragilis* in Cleve Love's Thomas No. 1, Rankin County, Mississippi. Letter in files of Mississippi Oil and Gas Board.

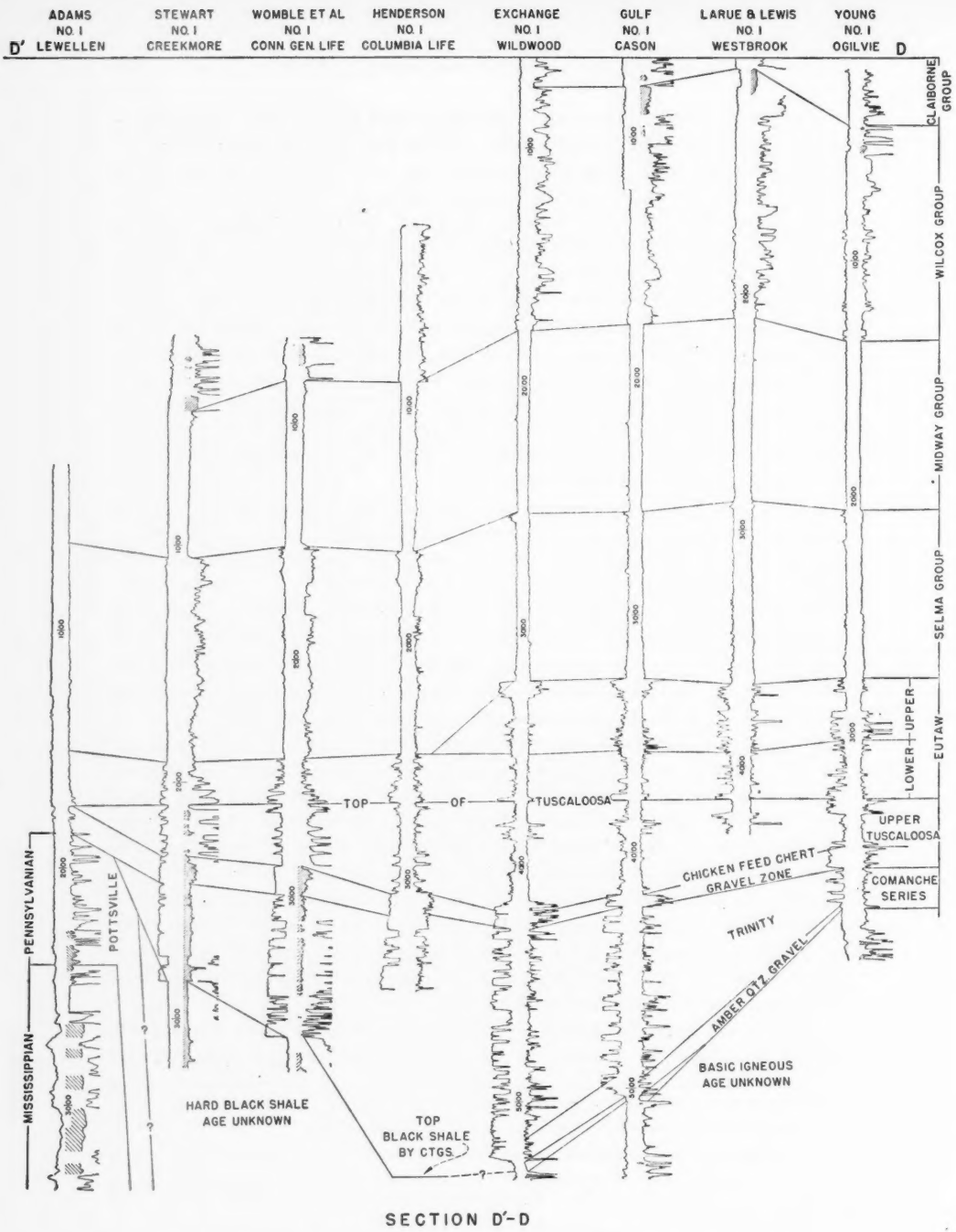


FIG. 6.—Section *D'D*. Electrical log correlation. Compiled from study of well cuttings and cores. Top of Tuscaloosa used as reference plane.

the Jackson dome. The thickness ranges from approximately 180 feet in northern Montgomery, Grenada, Yalobusha, and Lafayette counties to 900 feet in Sunflower County. The formation is thickest in southern Sunflower, eastern Humphreys, western Hinds, and Yazoo counties, but shows some local thinning in the Tinsley field. In the north-central part of the state the formation can be subdivided into the lower Eutaw and the upper Eutaw. The thin Eutaw section in northern Montgomery, Grenada, Yalobusha, and Lafayette counties is due to the absence of the upper Eutaw from the section. This absence may be explained either by non-deposition or by truncation (Fig. 6).

The lower Eutaw has a thickness ranging from 180 to 550 feet and lithologically is similar to both the Eutaw and the Tuscaloosa. It consists of laminated dark gray shales containing lignite, interbedded with beds of gray waxy shale, glauconitic sand, and white non-glauconitic sand. It contains abundant brown siderite and some very small siderite or ankerite pellets. The lower Eutaw is a transition unit that could be placed either in the upper Tuscaloosa or in the Eutaw formation. In Attala County its general character suggests the Tuscaloosa, but in Holmes County and in the Tinsley field in Yazoo County, it more closely resembles the Eutaw. In Humphreys, Sharkey, Sunflower, and western Yazoo counties, the lower Eutaw, and part of the upper Eutaw contain an abundance of red-brown shale associated with maroon and green-gray pyroclastic material. Nearer the Sharkey platform the entire Eutaw section has an increasing amount of water-laid volcanics and tuffaceous sands.

The upper Eutaw has a thickness of 300–350 feet and consists of calcareous to non-calcareous glauconitic sands, glauconitic and micaceous shales, and sandy shale. An abundance of brown sideritic sands and light brown glauconitic siderite is found in the lower 50–75 feet. The Wilburn sand of the Pickens field and the Perry and Stevens sands of the Tinsley field occur within the upper 120 feet of the Eutaw. Differences of opinion exist about the top of the Eutaw in the Tinsley field and in western Hinds and eastern Warren counties. Many geologists, on the basis of lithologic features, choose a Selma-Eutaw contact in these areas at a horizon which, on the basis of micro-fauna, is the Navarro-Taylor contact. The writer does not recognize any Eutaw of Taylor age. The upper Eutaw is probably equivalent to the Brownstown of South Arkansas. In the southeast part of the state, in south Forrest, south Perry, Greene, George, and Stone counties, the upper 200 feet, or approximately half of the entire Eutaw section, is chalk. The lateral gradation of the sandy upper Eutaw into chalk has taken place in a general north-to-south direction. As this chalk very closely resembles the overlying Taylor-Selma chalk, the lithologic determination of the Selma-Eutaw contact is nearly impossible. The approximate position of this contact is recognized by the highest appearance of an Austin micro-fauna.

SELMA GROUP

The Selma group, or at least some member of the group, underlies the greater part of the state. In central and northern Mississippi, it overlies the Eutaw with

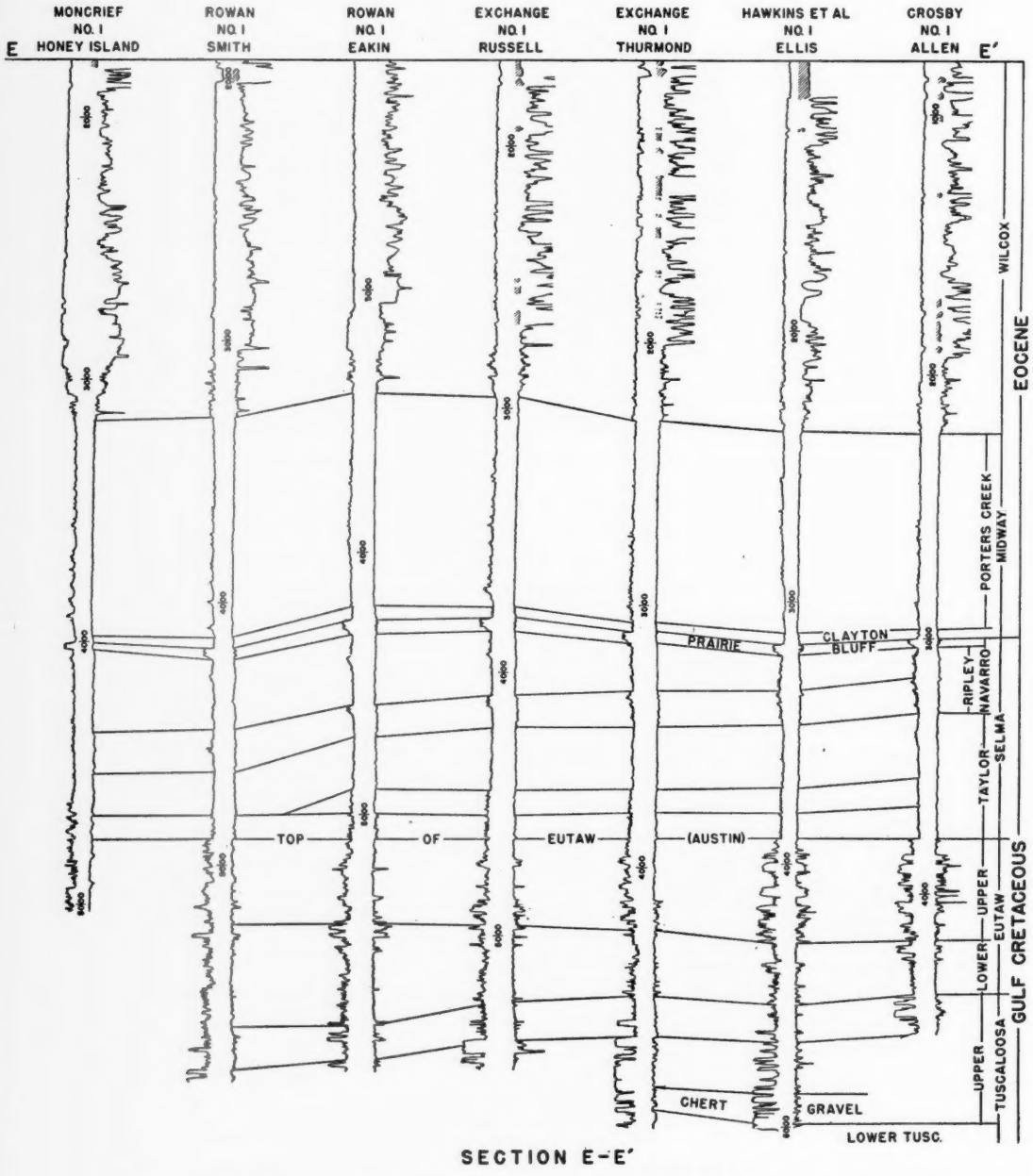


FIG. 7.—Section *EE'*. Electrical log correlation through Holmes County. Compiled from study of well cuttings and cores. Top of Eutaw used as reference plane.

marked unconformity. It has an approximate thickness of 350 feet in the Tinsley field, 475 feet in northwest Hinds County, and 1,500 feet in Wayne County. It thickens east and southeast. The Selma group, from oldest to youngest, is divided into the Taylor-Selma and the Navarro-Selma.[11] The writer does not include in the Selma group the chalks of upper Austin age which underlie the Taylor chalk in the subsurface of the southern Mississippi counties.

Taylor-Selma.—The Taylor-Selma has an approximate thickness of 230 feet in the Tinsley field and 1,050 feet in Wayne County. It consists of dark gray shale, dark and light gray calcareous shales, micaceous and glauconitic calcareous shales and argillaceous chalk or chalky shale. In the east half of the state, beds of calcareous shale and chalk are more numerous than in the western half. The dark gray shales very closely resemble those of the Porters Creek of the Midway. Near the Sharkey platform the Taylor-Selma contains beds of green and green-gray pyroclastic material, and an abundance of maroon volcanic material near the base. This sequence has been designated Eutaw by some geologists because of the water laid volcanics and the close resemblance of some of the shales to shales of the Eutaw.

Navarro-Selma.—The Navarro-Selma contains more chalk and marl than the Taylor-Selma. Generally, in the north part of the state it can be subdivided into the Ripley and Prairie Bluff. At the north part of its outcrop belt, in the northeast part of the state, the Ripley is predominantly sandy but grades downdip, and toward the south, into calcareous shales and chalks. The thickness of the Navarro-Selma ranges from approximately 100 feet in the Tinsley field to 450 feet in Wayne County. The Prairie Bluff, which consists of calcareous shale and chalk, has a thickness of 25–50 feet.

Jackson gas rock.—A series of white crystalline limestones, sandy limestones, and calcareous sands is found over the top and on the flanks of the Jackson dome. Some beds are exceedingly porous, and contain cavities filled with calcite. This series is called the Jackson gas rock and is the reservoir rock of the Jackson gas field.[12] It has an approximate thickness of 350 feet over the top of the dome, and 1,315 feet in the Mississippi Basin Oil and Gas Company's Gaddis-McLaurin No. 1, approximately 17 miles northwest of the top of the dome. Eight and one-half miles west of the Mississippi Basin well the gas rock is not present. Its greatest thickness occurs in a crescent-shaped area west of the dome. The micro-fauna of the gas rock differs radically from that of the normal Selma. From the nature of its occurrence, the Jackson gas rock appears to be a reef-type or platform deposit. It probably started forming during very late Taylor, grew through Navarro time, and may have resumed growth during Midway time.

The Woodruff zone, one of the producing zones of the Tinsley field, is believed to be a tongue or stringer of the Jackson gas rock. On the flanks of the Tinsley

[11] Study Group Project of the Mississippi Geological Society, *op. cit.*

[12] Watson Hiner Monroe and Henry Niles Toler, "The Jackson Gas Field," *Mississippi Geol. Survey Bull. 36* (1937).

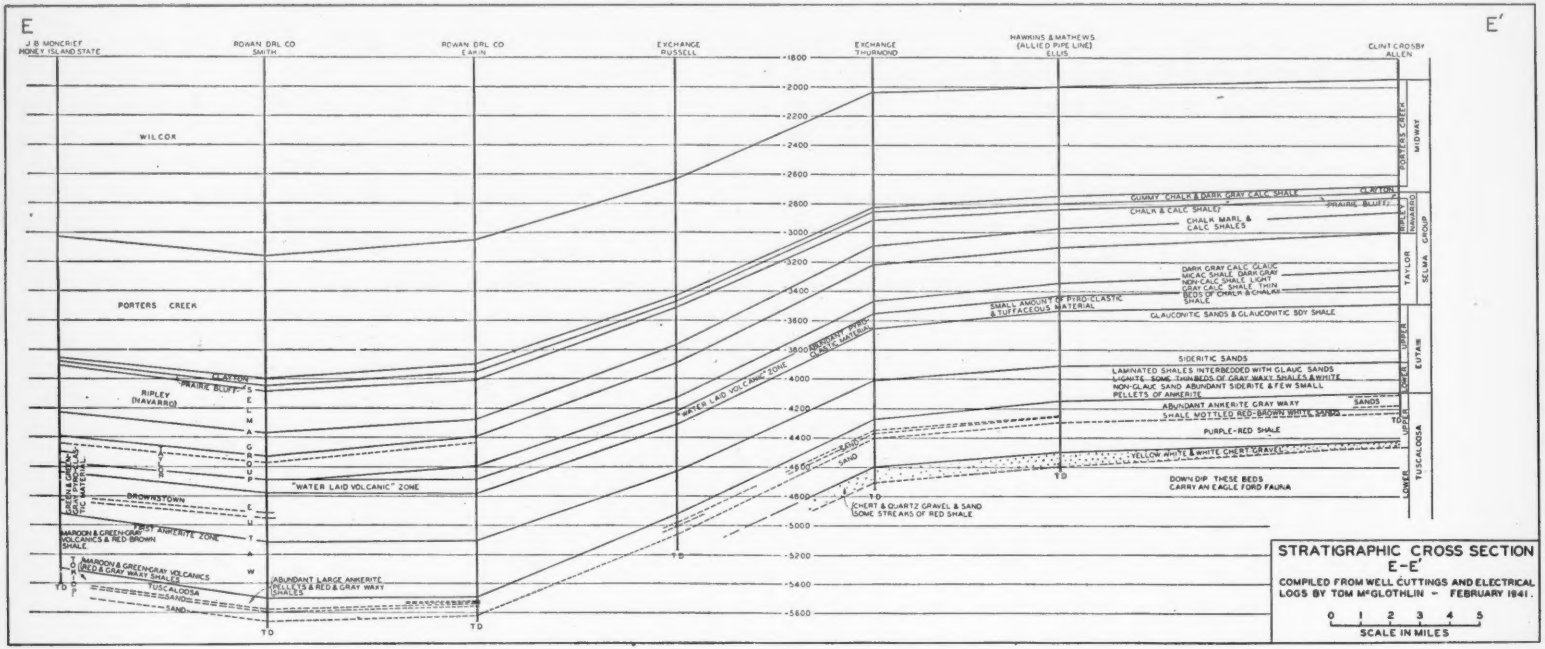


FIG. 8.—Section *EE'*. Northwest-southeast geologic section through Holmes County. Covers same area as Figure 7.

structure, the Woodruff zone tongues into normal beds of the Ripley. Locally it rests with apparent disconformity on beds of the Taylor-Selma, or is not present.

Monroe gas rock.—On the Sharkey platform, a similar lithologic unit, the Monroe gas rock, rests successively on beds of the Taylor-Selma, the Eutaw, the upper Tuscaloosa, and the Trinity. The Monroe gas rock is believed to be Navarro in age. The thickness of the Monroe gas rock, as typically developed, ranges from 5 to 100 feet in Mississippi. In Ray and Wolfe's Charping well, Issaquena County, a unit of approximately 300 feet of reworked red beds, calcareous sands, and thin beds of sandy limestone is thought by the writer to be of gas rock age. A similar unit was encountered in Cleve Love's Johnson No. 1, Hinds County.

Cenozoic Era—Tertiary System

Eocene Series

Midway Group

The Midway group of Mississippi in general is divided into two lithologic units which, from older to younger, are the Clayton and the Porters Creek. In Tippah County, on the outcrop, a salt-and-pepper sandstone, the Tippah sandstone, is well developed at the top of the Porters Creek. This sand does not continue far downdip in the subsurface although there are some Midway sands in the southeastern part of the state that are its probable equivalents. The Tippah sand has been correlated with the Naheola of Alabama.

The Midway is limited on the northeast by the outcrop but underlies the balance of the state except in those places where it has been pierced by salt domes.

Clayton.—The Clayton varies in character from white gummy chalk to gray calcareous shale, with beds of bentonitic shale present locally. It is in places difficult to differentiate lithologically from the underlying Prairie Bluff. Its thickness averages 25 feet.

Porters Creek.—The Porters Creek is a sequence of dark gray clay-shales with very little change from top to bottom. The upper part is typically lighter gray, is more silty, and contains a few grains of glauconite. It has a thickness of approximately 500 feet in the east part of the state in Clarke, Lauderdale, Kemper, Winston, Oktibbeha, Webster, Calhoun, and southeastern Lafayette counties and thickens generally downdip to approximately 1,000 feet. A thickness of 950 feet was encountered in the W. O. Allen's Henry No. 1, eastern Warren County, and 990 feet was encountered by the Black River Oil Company's Federal Land Bank No. 1, western Hinds County. The Porters Creek thins to a minimum of 55 feet over the Jackson dome, to approximately 400 feet over the Sharkey platform, and continues to thin westward in Louisiana toward the top of the unnamed structural feature of which the Sharkey platform is a part. In the area underlain by the Jackson gas rock, even on the flanks of the Jackson dome, the Porters Creek thins markedly, causing the Jackson gas rock to have a reef-like cross-sectional outline.

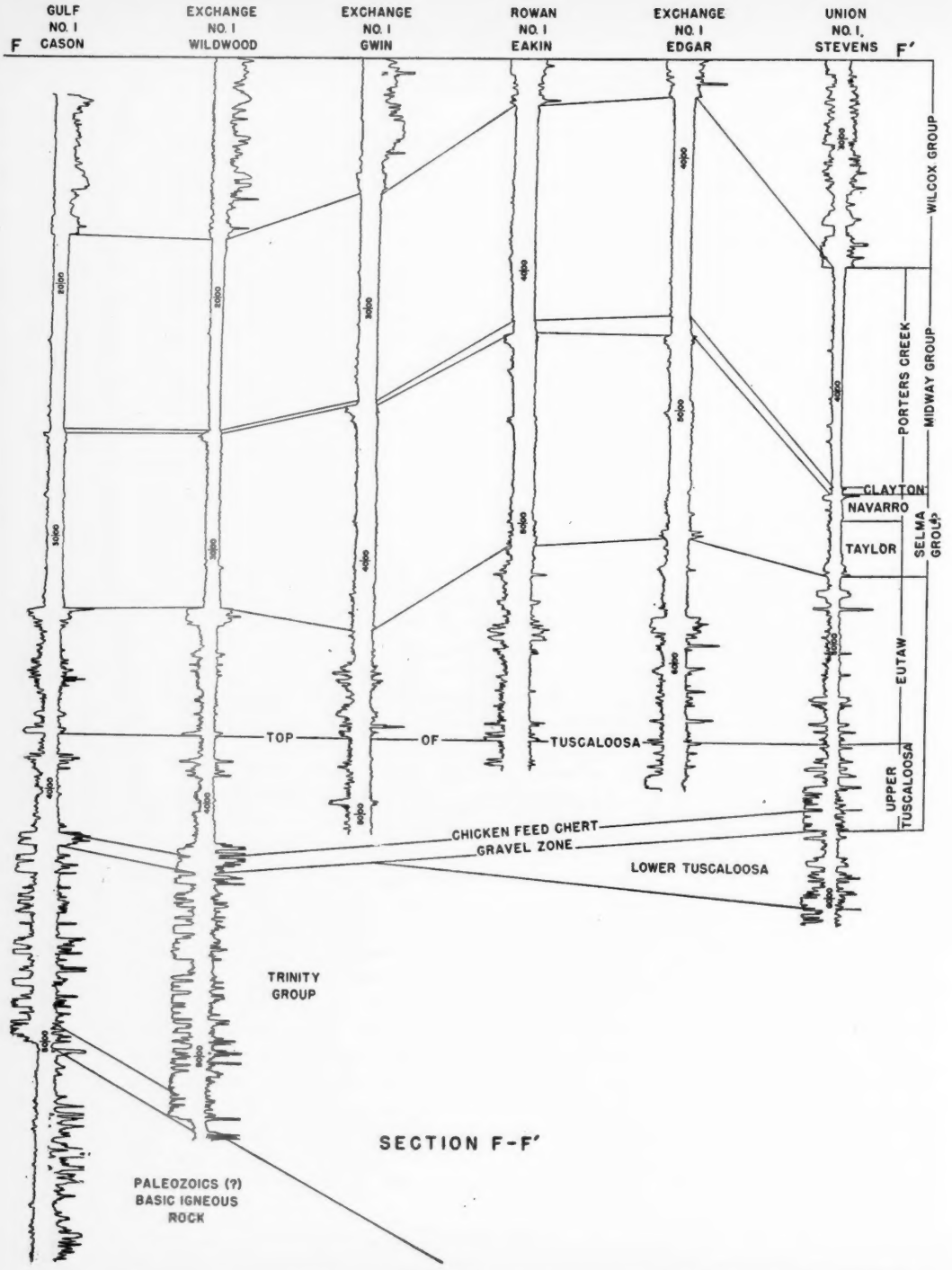


FIG. 9.—Section *FF'*. Electrical log correlation from southern Tallahatchie County to Tinsley field. Compiled from study of well cuttings and cores. Top of Tuscaloosa used as reference plane.

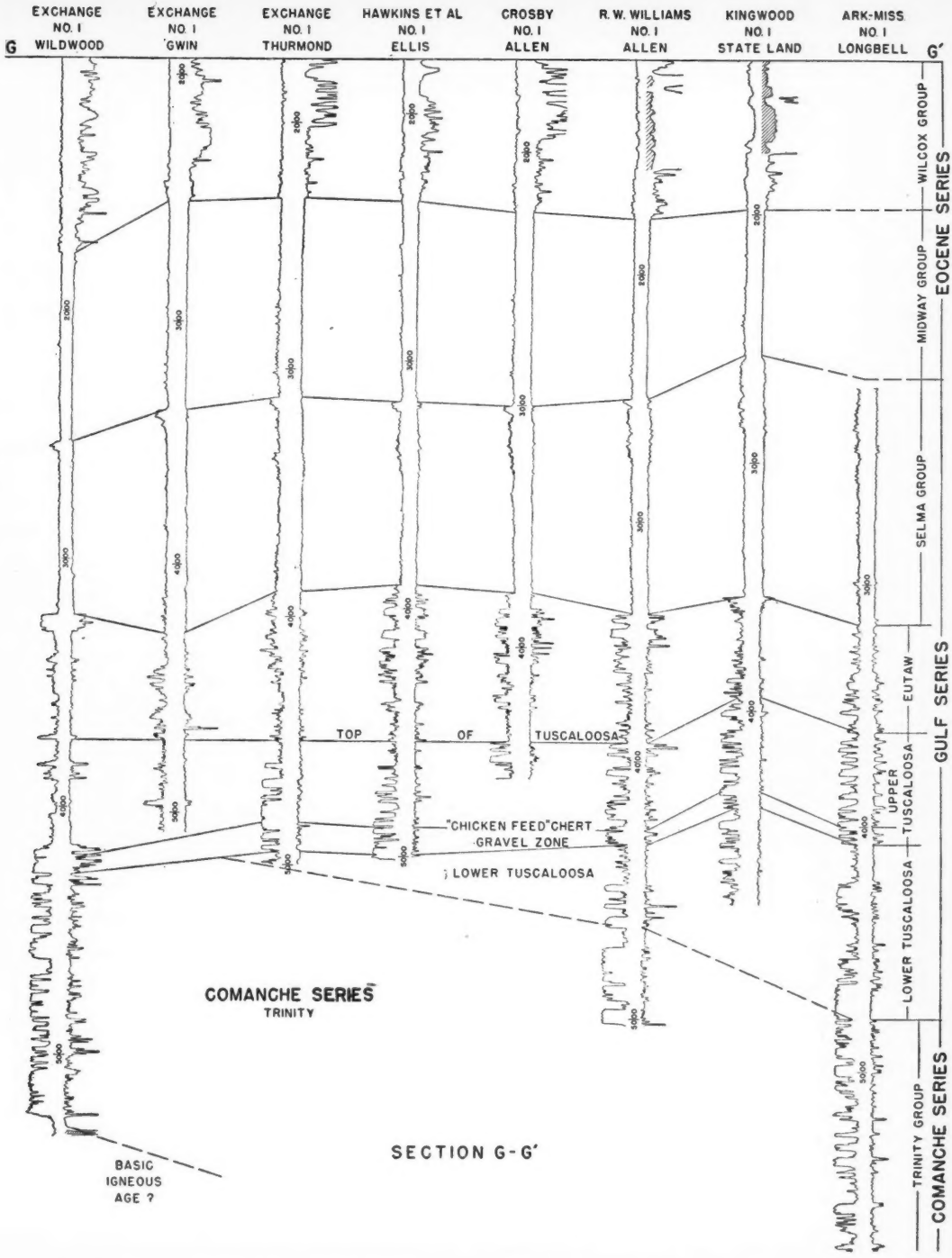


FIG. 10.—Section *GG'* Electrical log correlation from LeFlore County to Clarke County. Compiled from study of well cuttings and cores.

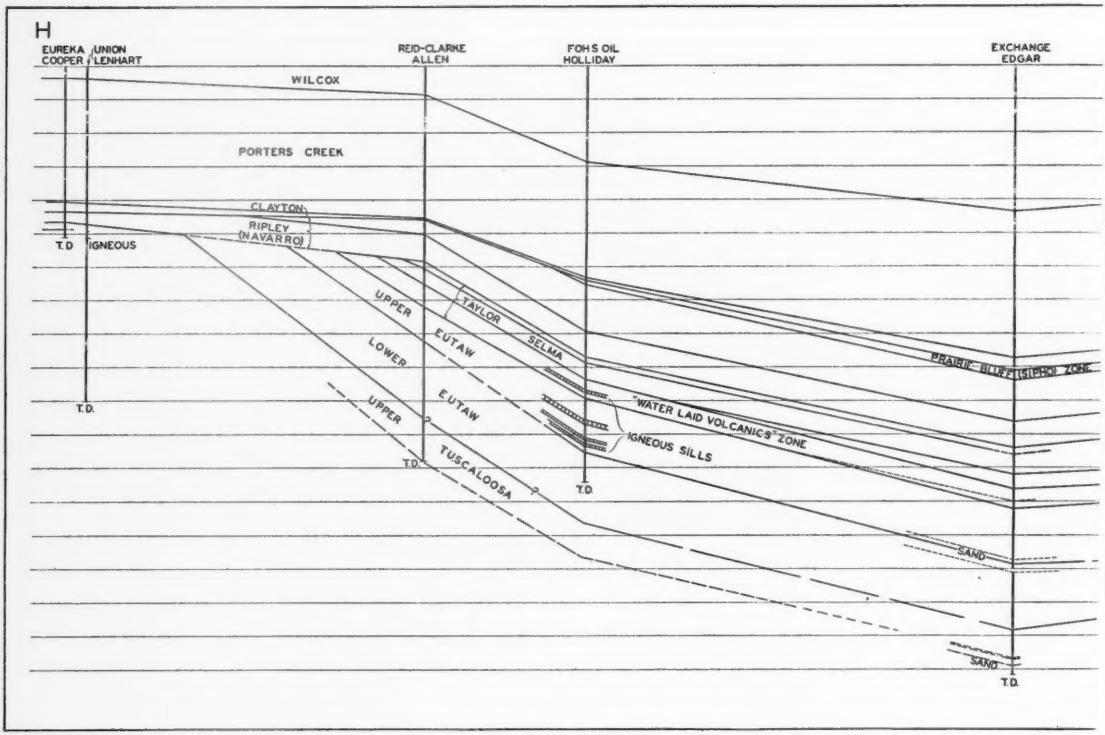
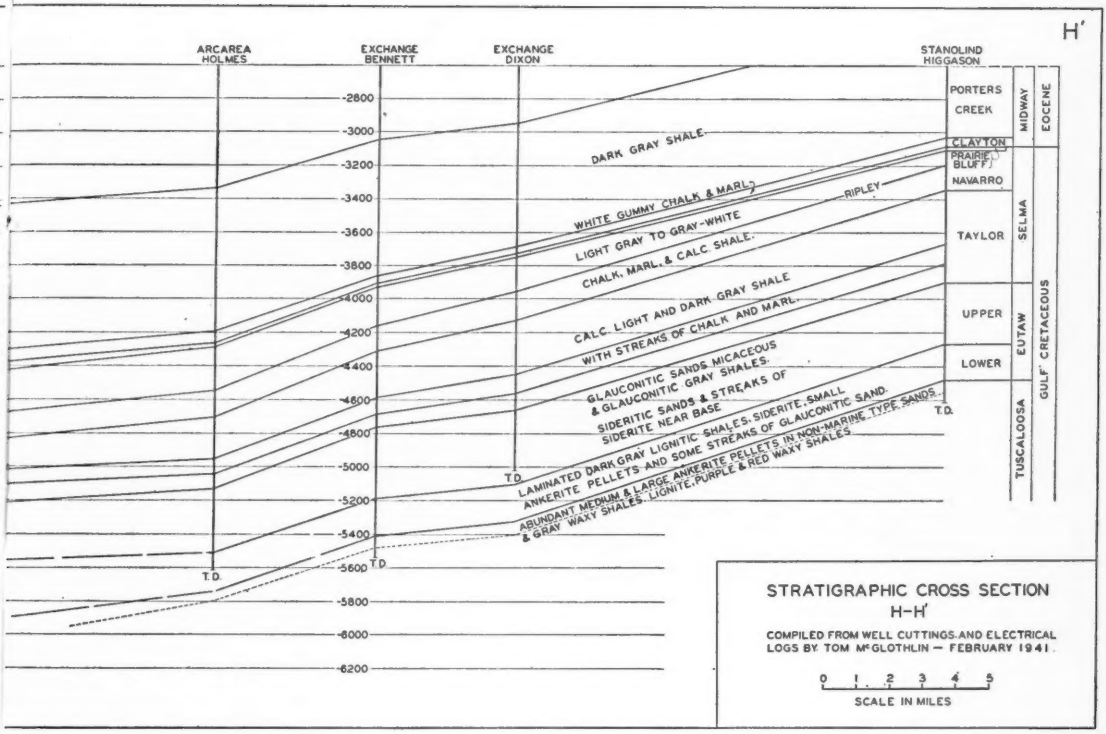


FIG. 11.—Section *HH'*. East-west geologic section from northern Sharkey



STRATIGRAPHIC CROSS SECTION
H-H'

COMPILED FROM WELL CUTTINGS AND ELECTRICAL LOGS BY TOM McGLOTHLIN — FEBRUARY 1941.

0 1 2 3 4 5
SCALE IN MILES

County to northwest Madison County.

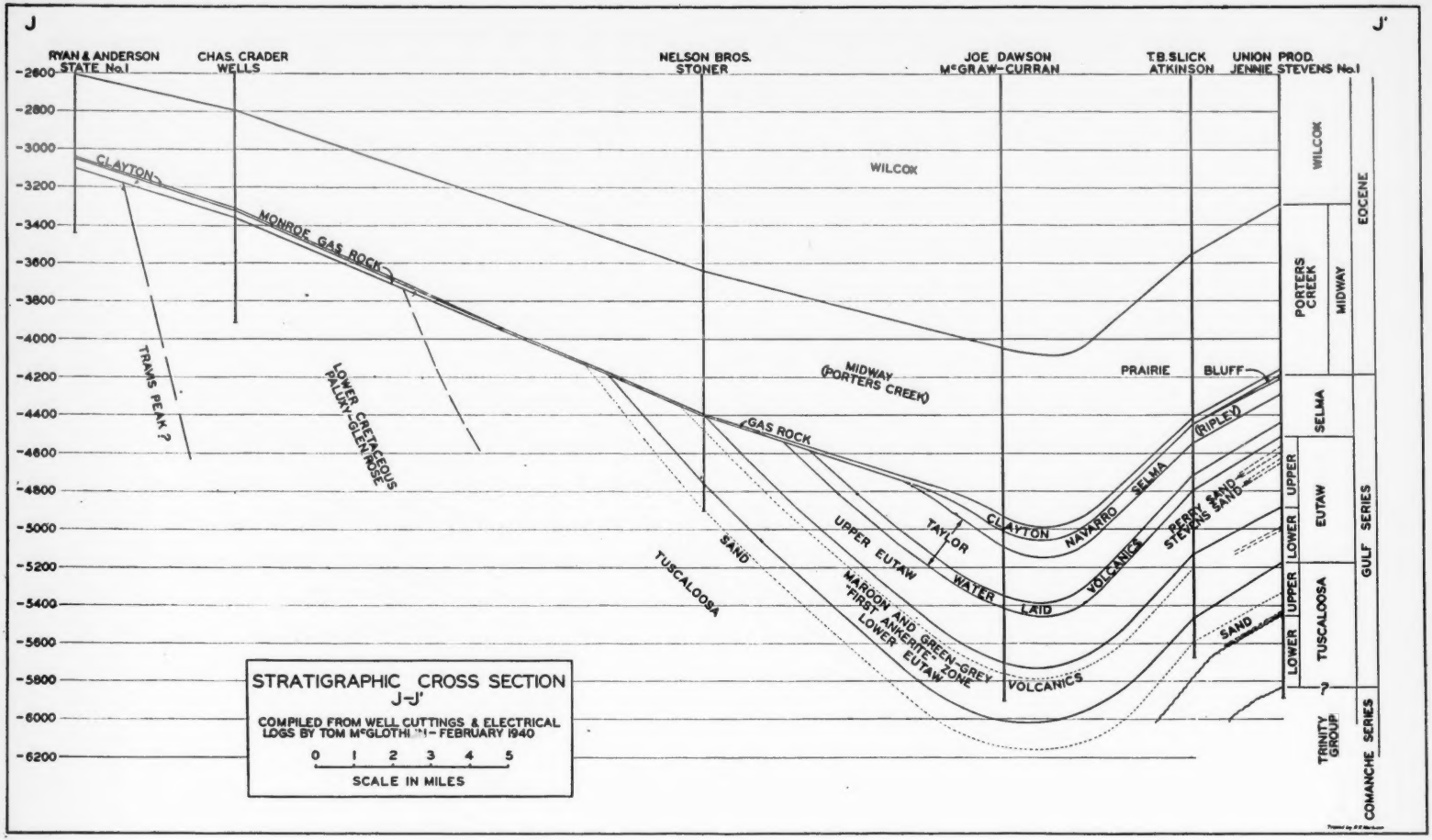


FIG. 12.—Section *JJ'*. East-west geologic section through central Sharkey County to Tinsley field.

WILCOX GROUP

The Wilcox outcrops in a wide belt striking roughly north and south, from Benton County on the north, to Lauderdale County on the south, and underlies the balance of the state. On the surface it has been divided from oldest to youngest into the Ackerman, Holly Springs, Bashi, and Hatchetigbee formations.[13] The last two are limited in Mississippi to Lauderdale County and contain fossiliferous marine beds. Mellen[14] has recently described a lithologic unit underlying the Ackerman formation. This unit, the Fearn Springs, according to Mellen, lies with disconformity on the Midway. The "Grenada formation," assigned to the Wilcox by early geologists in Mississippi, was found as a result of detailed field work in 1931 and 1932 by T. P. Conners and the writer to belong in the Tallahatta of the Claiborne group.[15,16] Richard Priddy,[17] formerly of the Mississippi Geological Survey, has noted Claiborne beds younger than the Tallahatta in the area shown to be underlain by "Grenada," on the Mississippi state geologic map. It is suggested here that the term "Grenada formation" be dropped. In Alabama the Wilcox group is composed mainly of marine beds, and can be subdivided into formations. The writer has never been satisfied with the subdivision of the Wilcox in Mississippi. With the exception of the Bashi and Hatchetigbee in Lauderdale County, Mississippi, the surface Wilcox deposits of this state might very well be called Undifferentiated Wilcox deposits. It may be true that general zones can be traced locally but the wisdom of giving formational rank to the "Ackerman" and the "Holly Springs" is questioned here. Exposures of typical "Ackerman" are plentiful in the area that is supposed to be underlain by the "Holly Springs sand," and many of the exposures of "Holly Springs" are probably Pleistocene terrace deposits.

In general, most geologists have made no attempt to subdivide the Wilcox of the subsurface. Certain zones can be traced locally but these zones are not definite enough for regional use. The Wilcox consists of medium coarse-grained unconsolidated sands, sandy and silty shales, carbonaceous shales, lignite, and some siderite. Southward from Hinds and Smith counties, glauconitic sands and marine fossiliferous shales appear. In southeast Mississippi, the Salt Mountain limestone is present in the approximate middle of the section. The Salt Mountain is not everywhere well developed and can not be used extensively as a key horizon. The Wilcox has a thickness of 900–1,000 feet in Attala, Montgonery, Carroll, Grenada, and Tallahatchie counties, but thickens downdip south and southwest. It thins to approximately 1,200 feet over the Jackson dome, to 1,800 feet in the Wiggins anticline area in Stone County, and to approximately 1,050 feet over the Sharkey platform. The section continues to thin westward in Louisiana toward the top of the "parent structure" of the Sharkey platform. The maximum thickness recorded in the state is 4,065 feet in the Phillips Petroleum Company's Newman

[13] L. W. Stephenson, W. N. Logan, and G. A. Waring, "The Ground Water Resources of Mississippi," *U. S. Geol. Survey Water-Supply Paper 576* (1928).

[14] F. F. Mellen, "Winston County Mineral Resources," *Mississippi Geol. Survey Bull. 38.*

[15] *Guide Book of Claiborne-Wilcox Field Trip of Mississippi Geological Society* (1940).

[16] *Ninth Annual Field Trip of Shreveport Geological Society* (1932).

[17] Richard Priddy, unpublished report on the resources of Tallahatchie County, Mississippi.

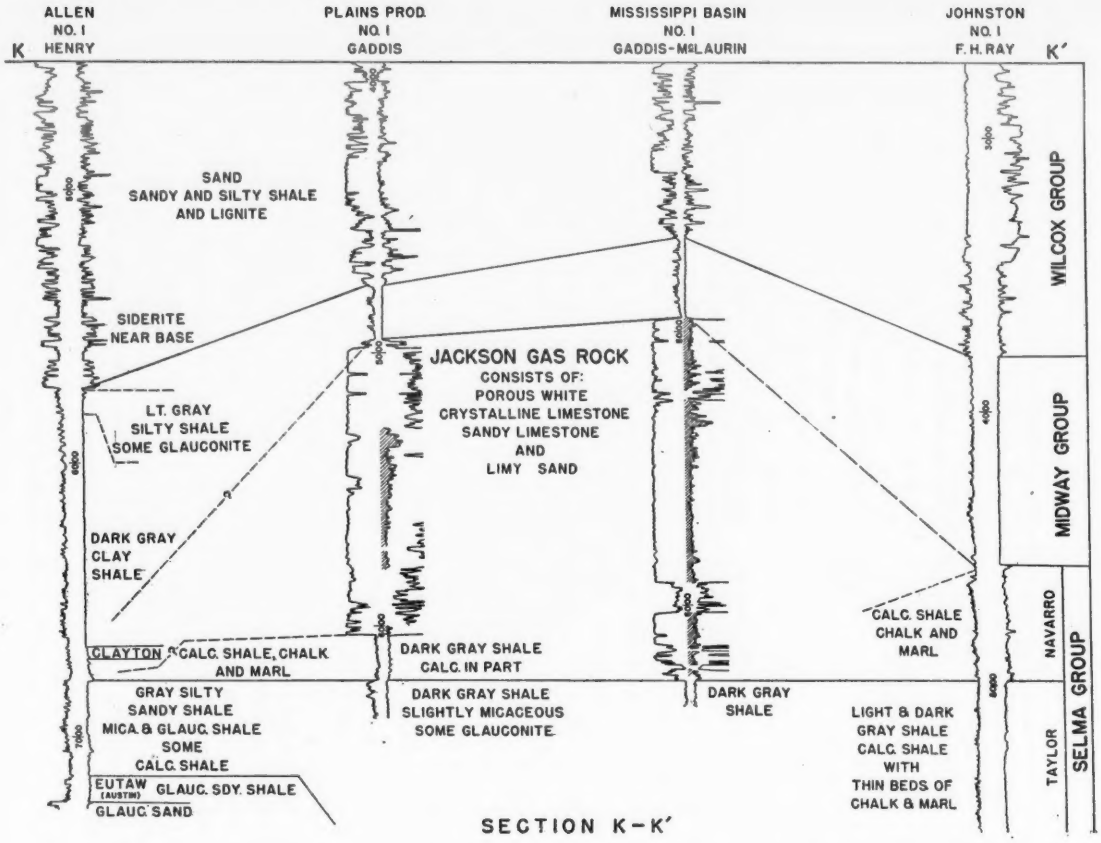


FIG. 13.—Section *KK'*. Electrical log correlation showing position of Jackson gas rock. Compiled from study of well cuttings and cores. Top of Taylor Selma used as reference plane.

No. 1, Perry County. In the opinion of the writer, this apparent thickness is greater than the true thickness of the Wilcox section because of steeply dipping beds. The Winona-Tallahatta unit and the Zilpha section also showed abnormal thickening in this well. In the Tide Water Associated Oil Company's Denkman Lumber Company No. 1, Lawrence County, the Wilcox had a thickness of 3,462 feet. With the exception of the Phillips' Newman No. 1, the Tide Water well encountered the greatest thickness of Wilcox in Mississippi.

CLAIBORNE GROUP

The Claiborne group underlies the west and south parts of the state. It crops out in a broad belt west and southwest of the Wilcox. It has a maximum thickness of approximately 2,500 feet in south Warren and north Claiborne counties, Mississippi. It thins generally east to about 500 feet in Clarke and Wayne counties, Mississippi, and continues to thin eastward to approximately 250 or 300 feet in the area of the Alabama River, in Alabama. The Claiborne group thins to about 1,100 feet on the Jackson dome, to approximately 1,600 feet on the Sharkey platform, and to a minimum of 340 feet on the Wiggins anticline. An isopach map on the Claiborne indicates that during Claiborne deposition a general structurally high area may have extended from the Wiggins anticline westward through the Florida parishes of Louisiana toward Wilkinson County, Mississippi, and Concordia Parish, Louisiana.

On the surface, the Claiborne in Mississippi is divided into the following units, from oldest to youngest: the Meridian sand, the Tallahatta, Winona, Zilpha, Kosciusko, Wautubee, and Cockfield (or Yegua). With the exception of the Wautubee and Tallahatta, all of the Claiborne lithologic units thin generally eastward. The Cockfield or Yegua pinches out in Alabama, a few miles east of the Mississippi-Alabama line. The Kosciusko, Zilpha, and Winona either pinch out between the Mississippi-Alabama boundary and the Alabama River, or merge with and assume the lithologic character and fauna of the Wautubee to form one lithologic unit—the Lisbon formation. The writer is inclined to favor the pinch-out theory and to correlate the Wautubee unit directly with the Lisbon formation of Alabama. Westward in Louisiana, the Tallahatta, Winona, and Zilpha of Mississippi become the Cane River formation; the Kosciusko continues as a unit and is the Sparta formation; the Wautubee is the equivalent of the Cook Mountain; and the Cockfield or Yegua retains both its lithologic characteristics and its name. It is a matter of opinion as to which of these Mississippi lithologic units should be given formational rank.

The Meridian sand, which has a thickness of 0–70 feet, is probably the equivalent of the Carrizo of Texas. It is very variable in thickness and in some localities is missing entirely from the section. It consists of loose yellow and yellow-brown micaceous sand, and white to brown-stained sand. The Meridian might be grouped with the Claiborne or it might be included in the Wilcox group. It is called Wilcox in the subsurface because its contact with the overlying Tallahatta

is more apparent in well cuttings and electrical logs than its lower contact with the unquestionable Wilcox.

The Tallahatta, at its outcrop consists of white to gray-white brittle claystone, "buhrstone" and sandstone, with glauconite sparingly scattered throughout the entire section. In the northwest part of the state the harder claystone and "buhrstone" ledges become thinner, and beds of unconsolidated sand and laminated carbonaceous clay-shales occupy the intervals between them. It is this facies that was originally designated as the "Grenada." The approximate thickness of the Tallahatta at the outcrop in Lauderdale County is 80 feet. Farther northwest in an area embracing Montgomery and Grenada counties it has a thickness greater than 150 feet. In the subsurface, the Tallahatta apparently merges with the overlying Winona, and the two become a lithologic unit consisting of blue-gray clay, white glauconitic chalk, and glauconitic calcareous sand. This subsurface unit has a thickness ranging from 250 to 350 feet.

The Winona at the outcrop is made up of ferruginous, brick-red, glauconitic sands. Lithologically it is practically the same as that of the Weches, its equivalent in Texas. Fresh unweathered material is dark green and contains calcareous material. The thickness varies from 60 to 80 feet.

The Zilpha is represented on the outcrop by approximately 30–100 feet of light gray to chocolate-brown clay and sandy clay. Its best development on the surface is in the north-central part of the state. In the subsurface, the Zilpha consists of chocolate-brown carbonaceous and fossiliferous clay-shales with lenses of glauconitic sand. It has a maximum thickness of 350 feet.

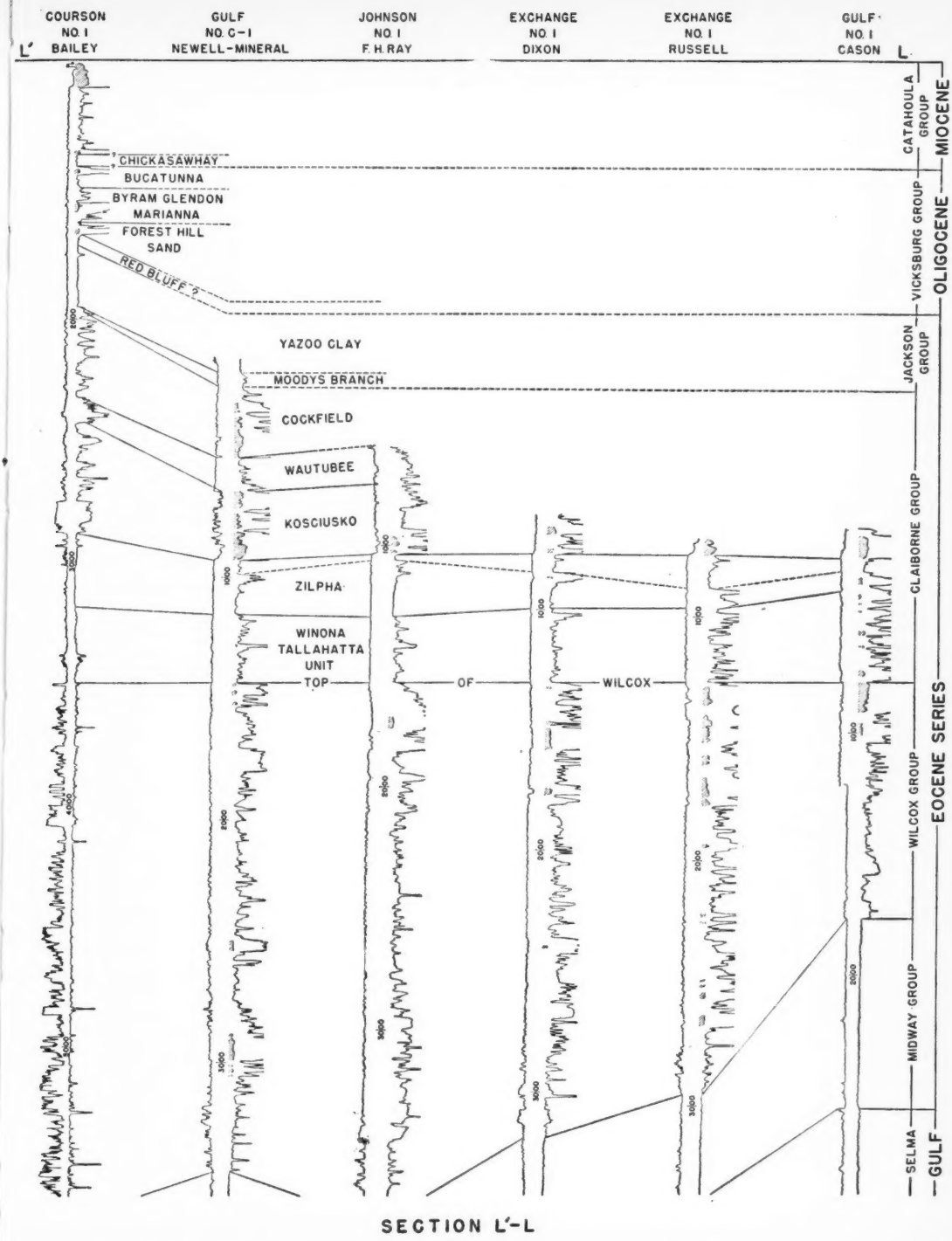
The Kosciusko ranges in thickness from that of a knife edge in the southeast part of the state in the Wiggins anticline area to slightly more than 900 feet in western Hinds County. It thins generally from west to east. It consists mainly of medium- to coarse-grained sand with some thin beds of sandy shale. Toward the south, in Copiah and Jefferson Davis counties it contains an abundance of carbonaceous material and lignite. On the surface in Attala, northeast Holmes and Carroll counties, it contains sandstone ledges that are indurated to quartzite.

The Wautubee has a thickness of approximately 150–200 feet, consists mainly of calcareous green sands and fine to silty, glauconitic shale, but has some ledges of gray-white sandy limestone in Clarke and Newton counties. In the subsurface in south Mississippi the greater part of the Wautubee grades to white gluconitic chalk. This chalky facies crops out in the Jackson fault area in Clarke County, Alabama.

The Cockfield, or Yegua, the youngest unit of the Claiborne group, consists of approximately 10–550 feet of irregularly bedded sandy clays, sands, carbonaceous chocolate-brown and gray clays, and lignites. It is thickest in the west-central part of the state and thins east and southeast. The Cockfield forms a small inlier on the top of the Jackson dome.

JACKSON GROUP

The Jackson group crops out in a belt striking southeast from southern Holmes and Yazoo counties to Clarke County. It is made up of two lithologic units, the Moody's Branch at the base and the Yazoo clay above.



SECTION L'-L

FIG. 14.—Section *L'L*. Electrical log correlation from Jefferson Davis County to southern Tallahatchie County. Compiled from study of well cuttings and cores. Top of Wilcox used as reference plane.

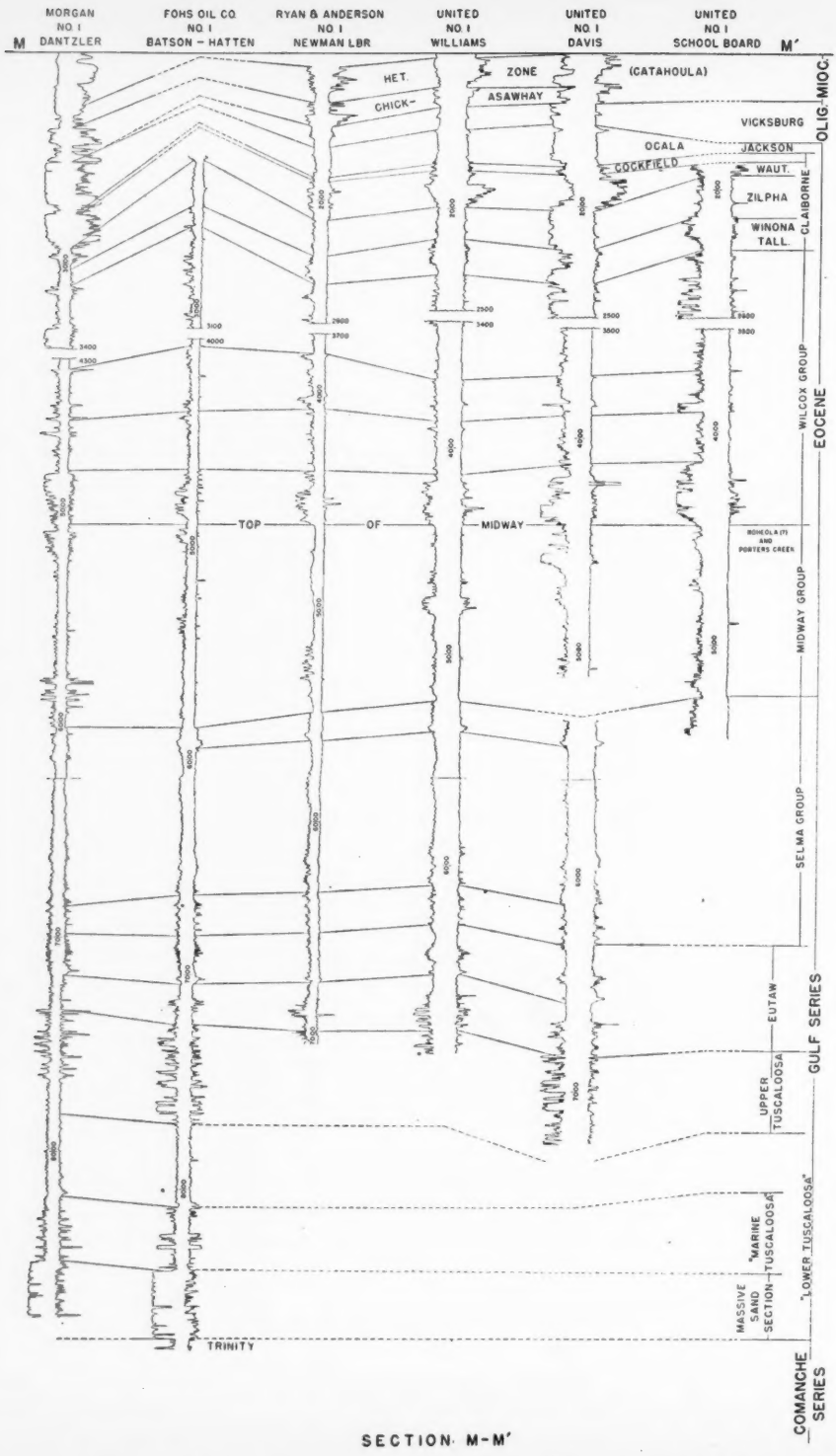


FIG. 15.—Section *MM'*. Electrical log correlation through Stone and George counties, Mississippi. Top of Midway used as reference plane. Compiled from study of well cuttings and cores.

The Moody's Branch is calcareous, fossiliferous green sand ranging in thickness from approximately 10 to 50 feet. It varies in thickness locally, has its greatest thickness in southern Holmes and Yazoo counties, and has a southeast regional thinning. The type locality is an exposure in a small stream known as Moody's Branch in the city of Jackson. The Moody's Branch lithologic unit forms a small inlier on the Jackson dome.

During 1929 and 1930 the writer did considerable field work, mapping the top and bottom of the Moody's Branch on the inlier at Jackson and in Yazoo, Holmes, Scott, and Clarke counties, Mississippi, and mapping the top of the Yazoo clay part of the Jackson and the top and bottom of the "Gosport," and other formations on the Hatchetigbee anticline in Alabama. At that time he was convinced, and still is, that at least the upper part, and perhaps all of the so-called "Gosport" of the Hatchetigbee anticline is Moody's Branch. The political boundary separating Mississippi and Alabama was apparently given weight in not only changing the name of the Moody's Branch, but also the age. There is a possibility that the Jackson-Claiborne contact is located in the approximate middle of the "Gosport," of the Hatchetigbee anticline.

The Yazoo clay has an approximate thickness of 500 feet in the west in Warren County, thins east to approximately 100 feet, and thins south to approximately 200 feet in Wilkinson County. The material consists of blue-gray fossiliferous clay with beds of bentonitic clay present locally. Discontinuous ledges of indurated marl are found on the surface in the southeast part of the outcrop belt.

The Ocala facies, a white to creamy white chalky reef-type limestone, represents the Yazoo over the Wiggins anticline in southeast Mississippi, and on the outcrop in the Jackson fault area in Clarke County, Alabama, and farther east. The Ocala facies appears to have been deposited upon submerged platforms or submarine topographic "highs." Interestingly, the Plains Production Company-Daly *et al.* Fort No. 1, Sec. 2, T. 6 S., R. 4 W., and McClanahan and Rose's Stafford No. 1, Sec. 24, T. 7 S., R. 3 W., Mobile County, Alabama, encountered the Yazoo facies of the Jackson. Both of these wells are southeast of the Wiggins anticline. The Ocala limestone has a thickness in Mississippi ranging from 140 to 250 feet.

OLIGOCENE SERIES

VICKSBURG GROUP

The Vicksburg group crops out in a narrow belt just south of, and parallel with, the Jackson outcrop. It is subdivided from the base upward, into the Forest Hill (in the west) and the Red Bluff (in the east), the Marianna (with the Mint Springs facies), the Byram, and the Bucatunna.

The Forest Hill has a thickness of approximately 100 feet in the west and disappears by pinch-out somewhere near the Mississippi-Alabama line. It wedges out over the Red Bluff which replaces it in the geologic section. The formation consists of loose friable sand with beds of dark gray and brown-gray laminated sandy clay.

The Red Bluff at its outcrop in Mississippi is fossiliferous, calcareous, light, brownish gray, blocky clay containing glauconite and selenite. The formation is

absent in west Mississippi but appears in the west-central part of the state. It increases from a feather edge to a maximum thickness of approximately 90 feet in west Wayne County, and gradually thins again toward the east. In Alabama it changes laterally into glauconitic limestone. In the southeast part of Alabama and in west Florida the Red Bluff on the surface has developed the "Chimney rock" facies of the Marianna which directly overlies it. This facies of the Red Bluff has a thickness of approximately 5 feet and can be differentiated from the Marianna "Chimney rock" by the abundance of glauconite and the presence of *Ostrea vicksburgensis* in fairly large numbers. In the subsurface in some parts of Mississippi a similar development of the Red Bluff may have occurred.

The Marianna is soft, creamy white to white "Chimney rock," locally indurated into hard ledges. The Mint Spring facies in the Jackson-Vicksburg area contains more clastic material than the typical Marianna of east Mississippi, Alabama, and west Florida, where it is approximately 98 per cent calcium carbonate. The Marianna and Glendon form the "Vicksburg lime" unit of the subsurface, with a thickness of approximately 40–100 feet. The thickness of the Marianna at the outcrop ranges from approximately 25 to 40 feet.

The Glendon is hard, gray-white crystalline limestone, having a thickness on the surface of approximately 30 feet in the west and 12 feet in the east. In the east part of the state, as in Alabama, it weathers to typical "horse-bone" appearance.

The Byram marl consists of approximately 25 feet of limestones locally indurated into ledges, calcareous clays, and sandy glauconitic marls. All of the material is abundantly fossiliferous. In the subsurface, the Byram is at places included in the "Vicksburg lime" unit.

In 1930 the Bucatunna was mapped originally by Miguel de Laveaga and the writer, as a member of the Byram, but later field work by Urban Hughes and the Shreveport Geological Society[18] brought out evidence that it may belong in the Miocene. There is still a difference of opinion about its exact age. The writer considers the Bucatunna to be a facies of the upper Byram. The Bucatunna at the outcrop in Wayne County consists of approximately 45–55 feet of dark gray and chocolate-brown clay, dark blue-gray sparingly fossiliferous clay, cross-bedded sands, bentonite clays, and bentonite. In west Mississippi the Bucatunna is represented by 30 feet of chocolate-brown and dark gray clays and sandy clays.

MIOCENE SERIES

Chickasawhay.—The Chickasawhay beds on the outcrop in Wayne County have been subdivided into lower and upper members.[19] They were also mapped originally by the writer as members of the Byram. Most geologists consider that they probably belong in the Miocene, but there still is a difference of opinion. Lithologically, the lower Chickasawhay very closely resembles the Byram. It consists of approximately 30 feet of limestones, fossiliferous clayey marls, and sandy marls. The upper Chickasawhay is less calcareous than the lower. It consists of approximately 25 feet of fossiliferous blue-gray blocky clay and fossiliferous

[18] *Guide Book of Eleventh Annual Field Trip of the Shreveport Geological Society* (1934).

[19] *Ibid.*

calcareous claystones. Near the top it becomes sandy and appears to grade into the overlying sand of the Catahoula. The writer is tempted to place the contact between the Oligocene and Miocene at the contact of the lower and upper Chickasawhay, since the two appear to be distinct lithologic and faunal units. Continued studies of the fauna of the Bucatunna and Chickasawhay beds will no doubt throw additional light on the ages of these lithologic units. Forrest Hood,[20] of the Ohio Oil Company, has reported some thin marl beds overlying the Bucatunna in a locality west of the city of Jackson. These marl beds may represent the Chickasawhay in the west-central part of Mississippi. The Chickasawhay beds are represented in the subsurface in southeast Mississippi by approximately 50–150 feet of sandy limestone, calcareous clay, and calcareous sand.

Catahoula and Heterostegina zone.—The Catahoula formation crops out in a wide belt in south-central Mississippi. It is composed of brown-gray and light green-gray clays, gray calcareous clay, lenticular sands and sandstones, and claystones, with some beds of sandy and bentonitic clays. On the surface in Jones and Covington counties, Mississippi, a zone of mottled gray and red-brown claystone, whose stratigraphic position is believed to be near the top of the Catahoula, can be traced. A wedge of sediments, thickening westward, intervenes between this mottled claystone zone and the typical sandstones and claystones of the Catahoula. A rough estimate of the thickness of this wedge in Copiah and Jefferson counties, Mississippi, ranges from 100 to 200 feet. The thickness of the typical Catahoula at the outcrop has been estimated at 300 feet or less in the east and 700 feet or more in the west.

In the Wiggins Anticline area in southeast Mississippi, the *Heterostegina* limestone rests directly on the beds of the Chickasawhay. A wedge of sediments intervenes between the *Heterostegina* and the base of the Catahoula, in south Mississippi and the florida parishes of Louisiana, thickening westward. An isopach map from the top of the *Heterostegina* zone to the base of the Catahoula (which shows the thickness of the wedge of Catahoula sediments plus the thickness of the *Heterostegina* zone) shows a minimum of approximately 50 feet in Stone County, and a maximum of 1,860 feet in south Wilkinson County. Whether or not there is a similar wedging from the top of the Catahoula to the top of the *Heterostegina* zone is not known. To the writer's knowledge, no diagnostic criteria relating to the top of the Catahoula exists in the subsurface of Mississippi. As the *Heterostegina* zone is not known to crop out, its stratigraphic position in relation to the mottled claystone zone of the outcrop has not been demonstrated. This mottled indurated clay, or claystone, is a product of weathering, and has not been recognized in the subsurface. The writer suspects that the mottled claystone zone has a stratigraphic position above the *Heterostegina* zone. If this is true, perhaps a wedging of post-*Heterostegina* sediments similar to the wedging of the pre-*Heterostegina* Catahoula sediments has taken place, and there may exist a progressive overlapping or overstepping of the younger sediments over the older. This suggested overlapping probably takes place from west-southwest to east-northeast.

[20] Forrest Hood, personal communication.

Post-Catahoula sediments.—The writer does not know of enough evidence, either lithological or paleontological, on the surface or in the subsurface, to subdivide the post-Catahoula sandstones, claystones, and clays in South Mississippi, into the Pascagoula clay and the Hattiesburg clay of Matson.[21] In 1931 Miguel de Laveaga and the writer worked out a series of mappable units in beds that were believed to be of Hattiesburg age, in Franklin and Wilkinson counties, Mississippi. This series of mottled claystones, sandstones, and calcareous green clays, having a thickness of approximately 360 feet, was subdivided into two units and tentatively called, from older to younger, the Knoxville and Fort Adams.[22] Approximately 2,450 feet of sediments lie between the base of the Knoxville and the top of the *Heterostegina* zone in the area of the Kirby's Lanehart No. 1, Sec. 22, T. 1 N., R. 2 W., Wilkinson County, Mississippi. The Knoxville and Fort Adams units have not been traced in the subsurface. Outcrops of beds that have been designated as Pascagoula, in Harrison County, Mississippi, are different lithologically from those designated as Hattiesburg in Wilkinson, Franklin, and Amite counties, Mississippi, but the possible relationship between the beds in the two areas has not been demonstrated. The Harrison County beds consist of brown-gray and blue-gray sandy clays, blue clays (locally fossiliferous), sands, and thin beds of locally indurated claystones. In general, the Harrison County beds do not indurate as extensively as those in Amite, Franklin, and Wilkinson counties. To the writer's knowledge, no detailed field work has been done to study the relationships of these beds to each other and to the Catahoula. Paleontological writings do not show whether these post-Catahoula sediments belong in the Miocene or Pliocene.

PLEISTOCENE AND RECENT

Willis.—A series of lenticular beds of gravel, red gravelly sand, red sandy clay, and ferruginous sand, formerly called the "Citronelle," has been renamed the Willis.[23] This series has an approximate thickness of 100–350 feet and crops out across the south part of the state. Beds of the same character, that are believed to be late Pliocene or early Pleistocene terrace deposits, are found on the surface in most of the state. The Willis does not form a definite unit. It so closely resembles the terrace deposits that its identification is questionable.

The loess deposits that form the bluffs just east of the Mississippi and Yazoo flood plains have an approximate thickness of 100 feet in the west and feather out in a distance of 50 miles east. Mastodon bones in the loess in Wilkinson County, Mississippi, indicate that these deposits are Pleistocene in age. The loam, sands, and clays that form the broad flat terrace plains bordering the Gulf Coast are thought to be either Pleistocene or Recent.

[21] L. W. Stephenson, W. N. Logan, and G. A. Waring, *op. cit.*

[22] *Guide Book of Jackson to Recent Field Trip of the Mississippi Geological Society* (1940).

[23] John Doering, "Post-Fleming Surface Formations of Coastal Southeast Texas and South Louisiana," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 19, No. 5 (May, 1935).

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 1 (JANUARY, 1944), PP. 63-122, 6 FIGS.

PETROLOGY OF BETHEL SANDSTONE OF SOUTH-CENTRAL ILLINOIS[1]

WILLARD D. PYE[2]
Chicago, Illinois

ABSTRACT

More than 40 mineral species and a large number of varieties found in the Bethel sandstone of south-central Illinois are described in detail. The petrographic study of the sandstone involves a complete analysis of the size, shape, and roundness distributions of the sand grains. The interrelationships and the vertical and lateral variations of these parameters are discussed. The origin and age relationships of the cements and certain relationships of the foregoing properties of the formation to porosity, permeability, and oil recovery concludes the study of the physical properties of the Bethel sandstone. From a synthesis of these data it is concluded that most of the Bethel detritus in the basin came from Llanoria on the southwest and that only small fractions came from Ozarkia, the Wisconsin highlands, and the Canadian shield.

INTRODUCTION

Following the recent return of Illinois as a prominent oil-producing state, a detailed sedimentological study of the Bethel sandstone[3] in a part of south-central Illinois was undertaken to obtain information that might be valuable in further prospecting. Special attention was paid to the mineralogy, cementation, and relationships of porosity and permeability to oil recovery. Besides the anticipated practical use of the study, it was hoped to obtain information on the origin of the Bethel sandstone detritus and its sedimentological history.

The area consists of Marion and Jefferson counties and those parts of Fayette, Effingham, Clay, Wayne, Hamilton, Franklin, Perry, Washington, Clinton, and Bond counties between T. 6 N. and T. 5 S., and R. 3 W. and R. 5. E. in south-central Illinois. Figure 1 shows the location of the area with respect to the state.

Samples for analysis consisted of cores from wells drilled into or through the Bethel sandstone.[4] Most of these cores came from wells drilled since 1940 and were collected at the well at the time of coring. The general coring procedure consists of beginning to core after the cutting-returns or action of the drill indicates

[1] Manuscript received, May 27, 1943. Published with the permission of the chief of the Illinois State Geological Survey. This report is part of a thesis on "The Bethel Sandstone of South-Central Illinois" submitted in partial fulfillment of requirements for the degree of Doctor of Philosophy at the University of Chicago. The writer wishes to acknowledge the kind coöperation of the Illinois State Geological Survey, which organization has made this study possible. Special acknowledgment is made of the interest taken in the investigation by Tracy Gillette and L. E. Workman of the Survey and the interest and assistance of the faculty of the department of geology of the University of Chicago where the research work was carried out.

[2] Present address: 1253 Harding St., Winter Park, Florida.

[3] Recently it has been suggested that the Bethel sandstone as it occurs in the center of the Illinois basin is not correlative with the Bethel at its type locality in Kentucky. The term "Bethel sandstone" used in this paper follows the current usage of the Illinois State Geological Survey, and is applied to that sandstone body between the overlying Paint Creek and underlying Renault formations in that part of the basin covered by this study. (*Cf.* P. L. Dana and E. H. Scoby, "Cross Section of the Chester of the Illinois Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), pp. 871–82.)

[4] The correlation of the samples as Bethel sandstone is based on work of the Illinois State Geological Survey and data furnished by The Carter Oil Company, The Texas Company, and Shell Petroleum Company, Inc.

that the top of the sandstone member of the Bethel formation has been reached; therefore, samples of the top of the sandstone are seldom available. Most of the cores start 2 or more feet below the top, and because only one core is usually taken, the total length of core available for study is ordinarily only 10–15 feet, although recovery is commonly imperfect. Very few entire cores were available. Instead, core chips had been collected by the Survey at approximately 1-foot intervals. For a number of wells, "mixed cores" were the only samples obtain-

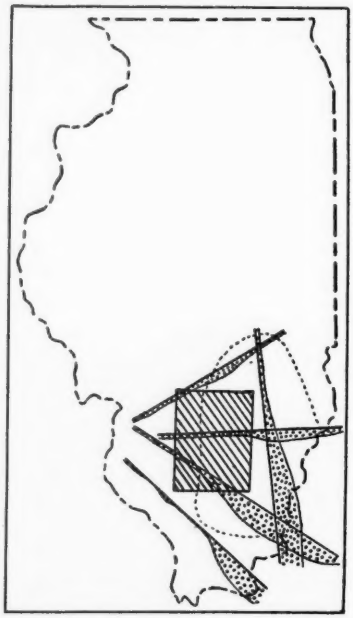


FIG. 1.—Shaded area indicates location in Illinois covered by this study. Dashed outline indicates limits of Illinois basin. Cross sections schematically show thickness relationships of Bethel sandstone to basin.

able; these consisted of a series of chips taken from discarded fragments whose position in the core was undeterminable.

Altogether about 600 core-chips were studied from more than 800 feet of Bethel sandstone taken from approximately 50 wells. In addition, a number of cores from wells outside of the area, representing sandstone formations higher and lower in the Chester series, were examined. From these cores, more than 150 samples from 44 wells were examined in detail by means of thin sections, heavy- and light-mineral concentrates, individual-grain studies, polished specimens, and leaching tests using water and acid. Also, the grain-size distribution, and round-

ness and sphericity distributions were determined;[5] porosity and permeability determinations were furnished by the Illinois State Geological Survey. Tables II and III give the location of the wells from which detailed analyses of the Bethel sandstone cores and brines were made, as well as a summary of the data.

TABLE I

KEY TO BETHEL OIL POOLS FOUND IN AREA (FIG. 1)

Letter on Map (Fig. 1)	*Name of Field*	*County*	*Location*	
			Township	*Range*
A	Alma	Marion	4 N.	2 E.
B	Centralia	Clinton, Marion	1, 2 N.	1 E., 1 W.
C	Cordes	Washington	3 S.	3 W.
D	Cravat	Jefferson	1 S.	1 E.
E	Dix	Jefferson	1 S.	2 E.
F	DuBois	Washington	3 S.	1 W.
G	East Patoka	Marion	4 N.	1 E.
H	Fairman	Clinton, Marion	3 N.	1 E., 1 W.
I	Hoffman	Clinton	1 N.	2 W.
J	Iola	Clay	5 N.	5 E.
K	Irvington	Washington	1 S.	1 W.
L	Louden	Effingham, Fayette	6, 7, 8 N.	2, 3, 4 E.
M	Mason	Effingham	6 N.	5 E.
N	Patoka	Marion	4 N.	1 E.
P	Salem	Marion	1, 2 N.	1, 2 E.
Q	Sandoval	Marion	2 N.	1 E.
R	St. Paul	Fayette	5 N.	3 E.
S	Tonti	Marion	2, 3 N.	2 E.
T	West Centralia	Clinton	1 N.	1 W.
U	Woburn	Bond	6 N.	2 W.
V	Woodlawn	Jefferson	2 S.	1 E.

SUMMARY OF STRATIGRAPHY AND RELATIONSHIP OF BETHEL SANDSTONE TO FORMATIONS ABOVE AND BELOW

The stratigraphic section of the Illinois basin can be summarized briefly as being composed of (1) a pre-Cambrian basement, (2) the pre-Upper Mississippian (pre-Chester) formations dominantly composed of limestone with some shale and sandstone, (3) the Chester series of eight sandstone formations alternating with limestone or shale formations, (4) the post-Chester (Pennsylvanian) formations of sandstones, shales, coals, and limestones, and (5) the post-Pennsylvanian intrusions, ore deposits, and glacial deposits.

The Bethel sandstone is the third formation above the base, or the second sandstone formation, of the Chester series, which consists of sixteen alternating sandstone and limestone-shale formations. This series may be briefly summarized as follows.[6]

[5] For the methods employed in making statistical analyses of the grain-size distribution and roundness and sphericity studies, see W. D. Pye, "Rapid Methods of Making Sedimentational Analyses of Arenaceous Sediments," *Jour. Sed. Petrology*, Vol. 13 (1943), pp. 85–104.

[6] J. M. Weller and A. H. Sutton, "Mississippian Border of Eastern Interior Basin," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 24 (1940), pp. 822–23.

TABLE II

KEY TO WELLS SHOWN IN FIGURE 1 AND DATA ON SANDSTONE SAMPLES STUDIED

Well No. (Fig. 1)	Well	Location			Formation	Notes[a]	Top of Bethel (Feet)	Depth of Sample (Feet)	Mean Phi Size (MΦ) Numerical	Sorting (σΦ)	Mean Shape (MΨ)	Porosity (Per Cent)	Permeability (Millidarcys)	Liquid Saturation (Per Cent)
		Sec.	Twp.	Range										
	Bond County													
1	Fox-Conroy, Buechlo 1	11	4N.	2W.	Bethel	s	1,256	1,241–43	3.40	.43	.88	—	—	—
						s		1,243–46	3.54	.43	.87	—	—	—
						m		1,246–58	3.40	.39	.89	—	—	—
2	Shell Pet. Corp., Wehrle 1	28	6N.	2W.	Bethel	t	1,012	1,024	3.96	.41	.84	—	—	—
								1,028	3.62	.37	.86	—	—	—
						t		1,029	—	—	—	—	—	—
	Clay County													
3	McBride, Smith 1	22	5N.	5E.	Bethel	t	2,308	2,317	3.86	.53	.84	—	—	—
								2,323	3.39	.36	.86	—	—	—
						t		2,327	3.45	.33	.88	—	—	—
					Cypress			2,163	3.38	.48	.87	—	—	—
								2,168	3.57	.35	.86		—	—
					Aux Vases			2,371–73	3.15	.55	.88	—	—	—
	Clinton County													
4	Bell Oil Co., Maibaum 1	12	3N.	3W.	Bethel	mt	1,137	1,152–59	3.05	.45	.87	—	—	—
5	Carpenter-Goldberg, C.B. & Q.R.R., 1	1	1N.	1W.	Bethel		1,365	1,372–73	3.14	.46	.83	—	—	—
6	Kesl-Fox, Storer 2	13	1N.	1W.	Bethel	b	1,363	1,363	3.34	.50	.84	22.2	715.00	73.5
						bt		1,368	3.36	.41	.89	22.2	388.00	73.5
						b		1,371	2.68	.44	.88	22.0	566.00	79.3
						bt		1,373	—	—	—	21.7	254.00	79.3
						b		1,375	3.24	.36	.88	21.7	244.00	79.3
						bt		1,379	—	—	—	21.8	260.00	75.0
						b		1,380	3.30	.32	.88	21.8	129.00	75.0
						bt		1,385	3.66	.39	.87	21.4	28.90	81.4
7	Martin, Heinzman 1	16	2N.	1W.	Bethel	t	1,466	1,467	3.80	.49	.85	—	—	—
						t		1,475	—	—	—	—	—	—
								1,476	4.32	.43	.85	—	—	—
8	Martin, Heinzman 2	9	2N.	1W.	Bethel		1,455	1,464	2.68	.45	.86	—	—	—
								1,469	3.46	.41	.86	—	—	—
								1,473	3.15	.33	.85	—	—	—
9	Niehoff *et al.*, Maddox 1	22	1N.	3W.	Bethel	mt	1,193	1,190–1,202	3.33	.61	.85	—	—	—
10	Texas Co., Gray 1	35	3N.	2W.	Bethel	m	1,200	1,204–25	3.02	.46	.87	—	—	—
	Effingham County													
11	Kilpatrick, Mason 1	22	6N.	5E.	Bethel	m	2,331	2,337–45	2.80	.32	.87	—	—	—
12	L. and W. Drilling Co., Davis 1	22	6N.	5E.	Bethel	t	2,347	2,354	3.55	.47	.87	—	—	—
								2,357	3.28	.41	.87	—	—	—
						t		2,363	2.99	.45	.88	—	—	—

TABLE II—*Continued*

Well No. (Fig. 1)	Well	Location			Formation	Notes[a]	Top of Bethel (Feet)	Depth of Sample (Feet)	Mean Phi Size (MΦ) Numerical	Sorting (σΦ)	Mean Shape (MΨ)	Porosity (Per Cent)	Permeability (Millidarcys)	Liquid Saturation (Per Cent)
		Sec.	Twp.	Range										
	Fayette County													
13	Bridges, Fiscus 1	21	4N.	1W.	Bethel	t	1,402	1,400–01	—	—	—	—	—	—
						t		1,401–02	—	—	—	—	—	—
						w		1,402–03	3.70	.35	.88	—	—	—
								1,407–08	3.62	.36	.87	—	—	—
						tw		1,409–10	3.85	.43	.88	—	—	—
*	Jarvis *et al.*, Sinclair 2	29	8N.	3E.	Paint Creek "Stray"	b		1,461	4.75	.76	.82	—	—	—
						b		1,468	3.92	.49	.86	17.5	5.87	—
						b		1,470	4.09	.73	.83	17.8	220.00	—
						b		1,472	3.30	.39	.87	19.2	—	—
						b		1,474	3.91	.61	.84	20.1	—	—
14	Kingwood, Aukamp 1	30	5N.	3E.	Bethel		1,899	1,902	3.55	.41	.87	—	—	—
								1,907	3.38	.45	.88	—	—	—
								1,913	3.49	.48	.87	—	—	—
15	Kingwood, Dayton 1	14	6N.	1W.	Bethel	tw	1,402	1,407	3.79	.41	.85	—	—	—
								1,410	3.29	.35	.87	—	—	—
						t		1,411	—	—	—	—	—	—
16	Kingwood, Torbeck 1	30	5N.	3E.	Bethel		1,907	1,907	3.65	.36	.86	—	—	—
						t		1,908	—	—	—	—	—	—
								1,909	3.58	.41	.88	—	—	—
								1,912	4.22	.46	.88	—	—	—
					Aux Vases			2,017–18	2.79	.57	.84	—	—	—
								2,022–23	3.51	.50	.88	—	—	—
	Franklin County													
*	Daly, Collins 1	34	7S.	2E.	Paint Creek "Stray"	m		2,557–67	3.46	.48	.86	—	—	—
17	Markham, Mitchell 1	18	5S.	3E.	Bethel	w	2,600	2,602	4.23	.49	.83	—	—	—
								2,604	3.95	.59	.84	—	—	—
						t		2,606	—	—	—	—	—	—
						t		2,610	3.94	.58	.81	—	—	—
						tw		2,613	3.58	.54	.89	—	—	—
	Jefferson County													
18	Kingwood, First National Bank of Woodlawn 4	35	2S.	1E.	Bethel	t	1,941	1,941–42	3.46	.36	.86	—	—	—
								1,943–44	3.63	.59	.83	—	—	—
						t		1,948–49	3.78	.59	.87	—	—	—
								1,952–53	3.26	.58	.85	—	—	—
								1,956–57	3.26	.48	.85	—	—	—
19	L. and W. Drilling Co., Sargent 1	22	1S.	2E.	Bethel	w	1,931	1,931–33	3.73	.48	.88	—	—	—
								1,933–37	3.68	.45	.86	—	—	—
	Johnson County													
*	Benedum and Trees, Cavitt 1	24	11S.	3E.	Bethel			1,844	3.67	.39	.88	—	—	—
								1,847	3.69	.41	.85	—	—	—

TABLE II—*Continued*

Well No. (Fig. 1)	Well	Location			Formation	Notes[a]	Top of Bethel (Feet)	Depth of Sample (Feet)	Mean Phi Size (MΦ) Numerical	Sorting (σΦ)	Mean Shape (MΨ)	Porosity (Per Cent)	Permeability (Millidarcys)	Liquid Saturation (Per Cent)
		Sec.	Twp.	Range										
	Marion County													
20	Adams Oil and Gas Co., Merryman 17	21	4N.	1E.	Bethel		1,392	1,392	3.97	.79	.85	17.4	165.00	85.5
						bt		1,394	3.58	.48	.86	17.4	286.00	85.5
						bt		1,402	3.61	.38	.86	12.0	0.68	89.0
						bt		1,406	3.54	.42	.87	20.5	158.00	80.0
						bt		1,411	—	—	—	21.9	163.00	88.0
						b		1,413	3.92	.75	.82	21.9	205.00	88.0
						bt		1,416	—	—	—	22.1	251.00	75.3
						b		1,418	3.55	.54	.86	19.4	89.50	73.9
						bt		1,421	—	—	—	14.4	148.00	78.3
						bt		1,423	3.45	.50	.87	14.4	78.30	118.0
21	Allen, French 1	19	4N.	3E.	Bethel	t	1,955	1,957	3.63	.43	.86	—	—	—
								1,961	3.85	.67	.87	—	—	—
								1,964	3.46	.46	.88	—	—	—
						t		1,965	—	—	—	—	—	—
								1,968	3.90	.55	.86	—	—	—
						t		1,972	3.39	.33	.89	—	—	—
22	Bell Oil Co., Inc., Helmrich and Payne, Stephens 1	35	3N.	4E.	Bethel	tw	2,460	2,465	3.92	.43	.84	—	—	—
						tw		2,470	—	—	—	—	—	—
								2,471	4.14	.66	.84	—	—	—
23	Helmrich and Payne, Spencer 1	25	3N.	2E.	Bethel	t	2,153	2,167	3.33	.27	.87	—	—	—
								2,169	4.31	.60	.83	—	—	—
								2,173	3.58	.34	.88	—	—	—
						t		2,174	—	—	—	—	—	—
						t		2,178	3.83	.48	.83	—	—	—
						t		2,183	3.43	.41	.88	—	—	—
24	Hudson-Hess, Young 1	7	2N.	2E.	Bethel	m	1,912	1,914–33	3.39	.56	.90	—	—	—
25	Shell Pet. Corp., Verviers 7	18	3N.	1E.	Bethel	w	1,426	1,431–32	2.91	.50	.83	—	—	—
						tw		1,434–35	2.78	.66	.82	—	—	—
26	Swan-King, Martin Cemetery 1	36	4N.	2E.	Bethel		1,995	1,999–2,000	3.35	.53	.88	—	—	—
27	Texas Co., Tate 1	5	1N.	2E.	Bethel	bt	1,690	1,693	3.83	.52	.81	10.0	2.03	—
						bt		1,695	3.13	.68	.87	17.3	150.00	—
						bt		1,697	—	—	—	16.0	42.10	—
						bt		1,700	3.62	.33	.87	15.2	19.20	—
						bt		1,702	—	—	—	16.1	31.60	—
						bt		1,704	—	—	—	17.4	152.00	—
						bt		1,706	3.57	.36	.86	15.6	23.70	—
						bt		1,708	—	—	—	14.8	284.00	—
						bt		1,710	—	—	—	17.1	234.00	—
						bt		1,712	3.95	.56	.81	15.1	178.00	—
						bp		1,716	2.40	.55	.84	19.1	696.00	—
						bt		1,717	—	—	—	13.9	273.00	—
						b		1,721	2.40	.55	.86	19.5	994.00	—
						bt		1,722	—	—	—	18.7	987.00	—
						bt		1,724	4.66	.48	.89	17.6	245.00	—

TABLE II—*Continued*

Well No. (Fig. 1)	Well	Location			Formation	Notes[a]	Top of Bethel (Feet)	Depth of Sample (Feet)	Mean Phi Size (MΦ) Numerical	Sorting (σΦ)	Mean Shape (MΨ)	Porosity (Per Cent)	Permeability (Millidarcys)	Liquid Saturation (Per Cent)
		Sec.	Twp.	Range										
	Perry County													
28	Blankenship, Bednarkwicz 1	24	4S.	2W.	Bethel		1,285	1,308	3.95	.36	.88	—	—	—
								1,312	3.56	.49	.87	—	—	—
								1,317	3.98	.44	.86	—	—	—
								1,319	3.50	.49	.86	—	—	—
29	Blankenship, City Park 1	13	5S.	3W.	Bethel	t	1,260	1,273	—	—	—	—	—	—
						t		1,286	3.77	.40	.86	—	—	—
30	Blankenship, George 1	23	4S.	1W.	Bethel		1,248	1,252–54	3.80	.44	.84	—	—	—
						w		1,258–60	3.27	.56	.87	—	—	—
								1,264–65	3.08	.51	.86	—	—	—
						w		1,271–72	3.51	.48	.87	—	—	—
31	Shell Pet. Corp., Schubert 1	23	4S.	2W.	Bethel		1,301	1,302	3.65	.36	.87	—	—	—
								1,307	3.50	.29	.87	—	—	—
								1,312	3.53	.32	.87	—	—	—
					Cypress			1,156	3.82	.45	.85	—	—	—
								1,159	3.46	.32	.87	—	—	—
					Aux Vases			1,377–78	3.65	.39	.87	—	—	—
	Washington County													
32	Gass, Keston 1	13	1S.	2W.	Bethel	tp	1,536	1,537	—	—	—	—	—	—
						wp		1,538	3.15	.56	.84	—	—	—
						wp		1,540	2.42	.63	.84	—	—	—
						tp		1,541	2.73	.59	.83	—	—	—
						p		1,542	2.96	.64	.83	—	—	—
						p		1,543	2.74	.63	—	—	—	—
						p		1,544	2.75	.76	.83	—	—	—
						p		1,545	—	—	—	—	—	—
						tp		1,547	2.77	.64	.84	—	—	—
33	Pugh, Wynn 1	33	3S.	1W.	Bethel	m	1,372	"Bethel"	3.50	.35	.86	—	—	—
34	Shell Pet. Corp., Brown 3	23	1S.	1W.	Bethel	t	1,540	1,543–44	2.86	.35	.86	—	—	—
								1,547–48	3.18	.20	.87	—	—	—
						t		1,552–53	3.35	.57	.85	—	—	—
35	Shell Pet. Corp., Dix 1	19	3S.	1W.	Bethel	t	1,359	1,362–63	3.41	.47	.87	—	—	—
								1,364–65	3.49	.48	.87	—	—	—
						t		1,367–68	3.54	.29	.87	—	—	—
36	Shell Pet. Corp., Kozuszek 2	23	3S.	3W.	Bethel	tw	1,232	1,240–41	3.69	.50	.85	—	—	—
						t		1,245–46	3.45	.55	.89	—	—	—
						tw		1,249–50	3.60	.42	.86	—	—	—
								1,254–55	3.54	.39	.87	—	—	—
						t		1,265–66	4.34	.42	.87	—	—	—
						t		1,272–73	3.23	.41	.88	—	—	—

a: If size and shape data are recorded, the grains were both projected and studied under the microscope. Heavy mineral analyses were made in some cases.
b: Porosity, permeability, and saturation data from R. J. Piersol, L. E. Workman, and M. C. Watson, "Porosity, Total Liquid Saturation, and Permeability of Illinois Oil Sands," *Illinois State Geol. Survey Rept. Inv. 67* (1940), pp. 35–40. Additional analyses of the cores and of cores from other wells are also given in the reference. The saturation and porosity data for the Kesl-Fox, Storer 2, Clinton County; and Adams Oil and Gas Company, Merryman 17, Marion County, are averaged over several feet.
m: Mixed core.
p: Polished section.
s: Questionable Bethel sample.
t: Thin-section.
w: Water analysis.
* Wells located outside of area shown on map.

The Chester series consists of a succession of alternating sandstone and limestone-shale formations of variable thickness and lithology, none of which possesses physical characters by which it may be certainly identified over long distances. The sandstones resemble each other more closely than do the limestone-shale formations. They are all fine-grained, more or less micaceous, commonly iron-stained, and vary locally from massive to thin-bedded or shaly. With few exceptions, they can be identified only by their relations to the underlying and overlying formations. The sandstones generally rest unconformably on underlying beds.

The proportions of limestone and shale in the other formations vary greatly both laterally and vertically. The shales are either calcareous or noncalcareous but rarely contain arenaceous beds. They range from very plastic to hard, brittle, and closely laminated and possess all colors common to shale. The limestones are of all types except dolomitic, range from dense to coarsely crystalline or oölitic, and from purely calcareous to argillaceous or arenaceous, are commonly cherty, and locally, are all shades of gray with reddish and greenish tints and some are stained brown, and may be massive or thin-bedded and shaly, evenly or irregularly bedded, cross-bedded, brecciated, or conglomeratic with rounded or angular pebbles of limestone and chert . . . .

The Renault formation underlies the Bethel sandstone and is a variegated shale, limestone, and sandy formation which is separated from the overlying Bethel sandstone by a minor unconformity. The Paint Creek formation overlying the Bethel sandstone is very similar to the Renault, so that the two shale-limestone formations are difficult to differentiate, especially where the Bethel sandstone is very thin. There is no evidence of an unconformity at the top of the Bethel. The shales of the Paint Creek are brightly colored and the limestones may be red, coarsely crystalline, and crinoidal.

Because no unconformity separates the Bethel and the Paint Creek formations, and because the lowermost member of the Paint Creek may include somewhat arenaceous shales, "practical" definitions have been developed by oil geologists. Usually the base of the lowest Paint Creek limestone is taken as the top of the Bethel formation, even though there may be a series of shales between the limestone and the top of the sandstone. However, some operators use the top of the first sandstone bed for the top of the Bethel formation. The present study is confined to the sandstone part of the succession.

Summary of Structure of Area

The area lies just northwest of the deepest part of the Eastern Interior basin,[7] which is bounded on the southeast by the Nashville dome, on the east by the Cincinnati arch, on the north and northeast by the Kankakee arch, on the west and southwest by the Ozark uplift, and on the south by the Mississippian embayment. The deepest part of the basin is found in the vicinity of White County,

[7] The term "Illinois basin" is frequently used synonymously with "Eastern Interior" basin. However, the present usage of the Illinois State Geological Survey confines the Illinois basin to the central deepest part of the Eastern Interior basin, or that part lying west of the LaSalle anticline and east of the Centralia-DuQuoin monocline, and extending as far north as Mattoon and south to the Shawneetown-Rough Creek fault zone. *Cf.* A. H. Bell, "Rôle of Fundamental Geologic Principles in the Opening of the Illinois Basin," *Econ. Geol.*, Vol. 36 (1941), p. 775.

Illinois, where it is estimated that there are more than 10,000 feet of sediments. Locally the basin is deformed by faults and folds. The most important of these are the LaSalle anticline, trending north-northwest and south-southeast along the east side of the Illinois basin, and the Shawneetown-RoughCreek fault zone, trending almost east and west through Shawneetown and cutting off the south part of the basin. Along this fault zone the maximum displacement is about 3,500 feet, with the uplift on the south.

The DuQuoin "anticline," which probably connects with the Centralia anticline, is essentially a monocline with the steep dip toward the east. It is broken by subordinate faults and terminates northward in a broad terrace which is locally domed. This structure trends almost due north and south and forms the boundary between the deepest part of the basin on the east and the shallower part on the west. Numerous other folds, faults, monoclines, terraces, domes, and noses of varying magnitudes are found within the basin. Most of the oil fields are associated with such structures, although porosity is a controlling factor in some fields. Figure 1 indicates the location of the area in which intensive study was carried out, as it is related to the Illinois basin; Figure 2 is a generalized structure map of the area contoured on the top of the Bethel sandstone.

Mineralogy

General mineral relationships

Although many mineral species occur in the Bethel sandstone, except for the main constituents they are found only as scarce grains and inclusions. Dominantly the Bethel sandstone is composed of quartz with a small percentage of feldspar, chlorite, and clay minerals. In some of the cleaner sands, a composition of 90 per cent or more quartz, with the remainder almost entirely feldspar and a small percentage of clay material, is common. In the impure sands the percentages of quartz and feldspar decrease, although the ratio between the two appears to remain about the same. The increase in the minerals other than quartz and feldspar is largely in the clay, chlorite, and glauconite. The heavy-mineral percentage does not vary appreciably. As the average size of the grains becomes smaller and smaller, approaching silt or clay, the sand becomes less pure and the light-mineral fractions decrease in proportion to the clay and chlorite fractions.

Ordinarily no carbonate is present or it is negligible in quantity, rarely more than a fraction of one per cent. However, in certain parts of the formation the sand may become calcareous and in some places the carbonate content may even exceed 40 per cent of the specimen, but these are merely discontinuous lenses. Part of the carbonate may originally have been detrital, with the sand in part precipitated from solution and in part derived from organic remains, but it is now all found as a recrystallized cement.

Heavy minerals are not abundant and the concentrates are largely made up of leucoxene and other opaques.

DETAILED DESCRIPTION OF MINERAL SPECIES

AMPHIBOLE GROUP

Anthophyllite.—One relatively fresh and very slightly rounded, colorless, non-pleochroic grain was found.

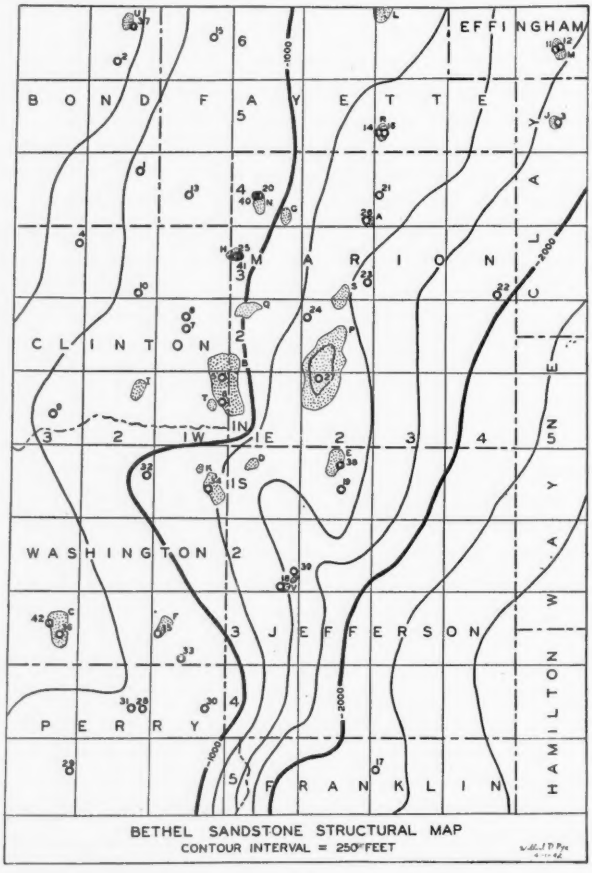


FIG. 2.—Structural map contoured on top of Bethel sandstone. Table I is key to Bethel oil fields shown on map; Tables II and III are keys to oil wells.

Hornblende.—All hornblende is much decomposed and is ordinarily completely altered to chlorite. Its original identity is revealed in most cases by traces of the amphibole cleavage still preserved; all amphibole outlines are missing. It is believed that most of the hornblende is the common green variety, as in the best

preserved part of the grains the pleochroism invariably is in shades of green. One grain had a relatively fresh central part with pleochroism of brownish green to green; the outer part was almost entirely altered to chlorite, yet the amphibole cleavage was still visible.

APATITE

Several varieties of apatite were observed. The most common detrital variety is colorless. Ordinarily it is moderately rounded to well rounded, and is either free of inclusions or full of small inclusions of both opaque and non-opaque minerals arranged irregularly. An occasional euhedral grain was found.

Blue-green apatite is found either as slightly rounded or euhedral detrital grains. It may be full of inclusions or may have none. However, most of the blue-green apatite (?) occurs as minute inclusions scattered through the quartz grains, especially in the pegmatitic and granitic types of quartz. Most of the inclusions are small, being only a few thousandths of a millimeter wide and proportionately long. There seems to be no gradation to the larger detrital grain sizes. Except for their color, which is bluer than the chlorite inclusions, and their prismatic shape, which may be somewhat corroded, these inclusions may closely resemble the fine chlorite inclusions in quartz. Some of the apatite (?) inclusions show minute inclusions within themselves. These appear as dark spots and can not be resolved even under the highest magnification.

CARBONATE

Calcite.—Calcite is not found as detrital grains in the sand; it occurs as recrystallized cement. In most places an original fossil outline is visible as a darker gray or greenish impurity in the calcite. Some of these outlines can be recognized as parts of crinoid stems and brachiopod valves. A few brachiopod outlines were distinct and the valves were filled with sand. On one of the better preserved fossils, the horizontal and vertical plates on the outside and inside of the shell were clearly visible, and the secondary calcite was deposited in the same crystallographic orientation as these plates. Some of this secondary calcite has come from the solution of primary calcite in adjacent parts of the fossil where sand grains have exerted excess pressure on those parts of the fossil where they have been in contact. Much of this dissolved calcite was then precipitated between the quartz grains where pressure was less than at the points of contact. The extremely sutured outlines of some of the fossil remains bear ample testimony of this repeated process of solution and precipitation.

The area containing calcite is ordinarily much larger than is indicated by the fossil outline and shows evidence of enlargement. However, in some carbonate areas there is no evidence of any fossil structure. There appears to be very little difference in direction of enlargement of the calcite grain or aggregate, although it may be longer in a plane parallel with the bedding. However, this may be because this is commonly the plane containing the largest section of the original structure.

In most areas, all the calcite has the same crystal orientation and is optically continuous except where it occurs in very large patches or in large fragments of shells. In general, the calcite is twinned and shows good cleavage. Good crystal outlines are not present unless the calcite has recrystallized in a pore which is free of clay or other material. It is only rarely that calcite occupies a pore that is also occupied by clay, and in these cases either it may incorporate the clay and be finely crystalline, or it may occupy any space not occupied by the clay. Rarely is there any evidence of the shoving of interstitial material by growing calcite, although in some places clay has been shoved aside and a good face of calcite developed.

There is evidence of calcite replacing quartz in a few places. The replacement of the secondary silica enlargements of quartz occurs more commonly than does replacement of the original quartz core.[8]

Dolomite.—Dolomite is not abundant in the Bethel sandstone, though it occurs in good crystalline rhombs interstitially with the other detrital grains. It has a greater tendency than calcite to shove clay minerals out of the way so that it can develop its own form. In one place it appears to be replacing calcite along the cleavage, dating it as post-calcite in age.

Iron-bearing carbonate.—This is a relatively rare form of carbonate; it is indicated by indices of refraction higher than that of calcite. Also, the cleavage directions are commonly red due to oxidation of the iron to hematite, or to iron precipitated from solution along the cleavage planes by the carbonate. It does not crystallize distinctively from the calcite and appears to be altered from original calcite.

CHLORITE GROUP

A large proportion of the interstitial material in the Bethel sandstone is chloritic. It is exceedingly fine-grained and came in as a clay with the quartz or has been derived from the alteration of the mafic minerals, largely since deposition, although some of the alteration may have been pre-depositional. Some included leucoxene or magnetite grains are found in the chlorite, or these may be merely on the surface of a chlorite mass as though at some time the chlorite flake had been in contact with either altered ilmenite or magnetite. Some of the chlorite has been incipiently oxidized to limonite and hematite.

There is considerable evidence of secondary growth of chlorite. This is shown most clearly in one of the grains of oligoclase where, since deposition, chlorite has grown into the grain along a cleavage plane and apparently by the force of crystallization has split off a corner and entirely surrounded the fragment. However, incipient fracturing during transportation or compaction may have aided the growth of the chlorite. The connection of the feldspar fragment with the parent grain is clearly evident, as the parts fit together perfectly with sharp

[8] P. D. Krynine, "Petrology and Genesis of the Third Bradford Sand," *Pennsylvania State College Min. Indus. Exp. Sta. Bull. 29* (1940), p. 24.

edges and there is no evidence of replacement boundaries. In another example a small fragment of yellow-green chlorite is surrounded by a border of darker green secondary chlorite.

Small amounts of chlorite are found associated with almost every grain of quartz and separate the original quartz core from the later silica enlargements. Those inclusions which outline the original quartz grains represent the recrystallized clay which originally surrounded the quartz grain at its time of deposition. They are pale greenish, irregular-shaped, and have been enveloped by the secondary quartz which surrounds the original grain. In places, several successive layers of secondary silica are thus separated. Some of the cores of the quartz grains are full of pale green chlorite which occurs either as rounded flakes, highly irregular flakes, vermicular inclusions, or in some cases, flakes folded back sharply upon themselves.

Although a number of varieties of chlorite are present, as is indicated by optical data and the varying intensities of color which range from deep green to nearly colorless, penninite is most important and abundant. These varieties of chlorite, calcite, and sericite seem to be the three minerals that are capable of replacing quartz. The deep green chlorite varieties are ordinarily associated with the clay and mafic minerals, and penninite is associated with quartz and chalcedony, although a deep green chlorite is the usual variety occurring in the quartz inclusions.

CLAY MINERALS

The clay minerals form a definite group and should be differentiated from those minerals which occur in the "clay-size" range. This clay-size range includes any material finer than 1/256 mm. in diameter, irrespective of its chemical composition. In the Bethel sandstone the clay-sized material is dominantly made up of sericite, fine chloritic material, glauconite, and other hydrated oxides, as well as the clay minerals. The clay minerals are present only as fine aggregates and could not be individually identified.

CORDIERITE

One grain of cordierite was found. It occurred as a formless mass whose birefringence and indices were about the same as those of quartz, but it differed from quartz in that it was biaxial positive with a moderate axial angle. Its most characteristic feature was the abundance of dark, irregular, clay-like inclusions. Initial transportation rounded the grain fairly well, after which it was deposited and coated by secondary silica, then eroded again, re-deposited, and re-coated with silica while in the Bethel sandstone. During the last cycle one corner of the grain was broken, twisted, and recemented to the original grain by secondary silica. This breaking probably took place during consolidation or structural deformation of the Bethel, otherwise the fragment would have been separated from the parent grain. Although cordierite is formed almost exclusively under metamorphic conditions and is quite unstable in other environments, it has been preserved in the Bethel sandstone because of its armor of secondary silica.

EPIDOTE GROUP

Epidote.—Several grains of epidote were found. All are well rounded but with no apparent enlargement or secondary alteration. They are light yellow and faintly pleochroic, but have a high birefringence indicating a moderately high iron content.

Clinozoisite (?).—One grain was found which was tentatively identified as clinozoisite or zoisite. It was colorless, non-pleochroic, and showed relatively low birefringence. It contained numerous small "dusty" inclusions.

FELDSPAR GROUP

All the feldspars are similar in that they contain some inclusions but not in such abundance as to warrant calling any grain a pegmatitic feldspar. All grains show alteration, the orthoclase being in general most altered, then the plagioclase, and the microcline least altered. Cleavage has commonly controlled the directions of alteration and has facilitated fracturing and breaking during consolidation of the sand, especially where a feldspar grain was caught between quartz grains. All varieties show some secondary enlargement, with the possible exception of microcline. Shape and roundness are controlled by cleavage; some grains show considerable rounding but others are angular with corners resulting from recent fractures along cleavage directions.

Microcline.—Although microcline may show some alteration, it is ordinarily the freshest of the feldspar varieties. It is commonly better rounded than the other feldspars and may show some enlargement. One grain had been broken, twisted, and recemented as well as enlarged. The enlargement showed no twinning and appeared like secondary quartz except that the index was less than that of balsam and almost identical with that of the adjacent microcline. This enlarged grain had been rounded and redeposited in the Bethel formation, but since deposition it has suffered no further enlargement.

Orthoclase.—The occurrence of orthoclase is fairly common in the Bethel sandstone, although less so than the plagioclase feldspars. In general it is untwinned and highly altered to either kaolin or sericite. Rare examples exhibit Carlsbad twinning. Minute inclusions are present in some of the grains, but are nowhere abundant enough to suggest a pegmatitic origin. One piece shows some secondary enlargement that developed during an earlier cycle of erosion. During the last cycle the enlargement was almost entirely removed. Fracturing and breaking along cleavage planes during compaction is shown in some grains where they have been pinched between quartz grains. A few grains show what appears to be a micrographic intergrowth of quartz and orthoclase.

Plagioclase.—Plagioclase, varying in composition from albite to acid labradorite, is found, but 95 per cent is basic oligoclase in composition. Alteration of the plagioclase is mainly to sericite and is controlled by the cleavage planes. However, the principal direction of alteration is parallel with the twinning planes. Minor amounts of kaolin and pale greenish chloritic mica are also present as al-

teration products. However, alteration is not extreme and some grains are entirely fresh. All grains, from the most acidic to the most basic, may show some enlargement, but this is very rare and appears to have taken place in a previous cycle as it has been largely removed and the grains show no enlargement since deposition. In some of the more basic feldspar, enlargement is not optically continuous—the core and secondary growth extinguish differently. This may be due in part to a difference in composition of the secondary plagioclase.

FLUORITE

One grain of fluorite occurred as an isotropic grain of very low index. It was perfectly euhedral and showed no evidence of abrasion. The grain occurred interstitially between quartz grains and was surrounded by secondary calcite cement. No evidence of replacement of calcite by fluorite existed. The grain appeared to be pre-calcite in origin and authigenic.

GARNET

Garnet is exceedingly scarce, only three grains being found. These were all angular and showed conchoidal fracture and almost no rounding. Two of the garnets were clear and slightly pinkish; the third one was much darker and contained many inclusions, as would be expected in a metamorphic garnet derived from a low-grade schist. The other two might have an igneous or vein origin, although they could be metamorphic. There was no evidence of solution of the garnets as would be expected if their absence from the Bethel is due to removal by ground water. The angularity is surprising since it greatly exceeds that of any other variety of mineral. They are very uniformly angular in all directions and not in just one direction as might be expected were the angularity due to fracturing during disaggregation. Solution can produce angular edges, but ordinarily there is also some evidence of pitting or other corrosion of the surfaces. The surfaces on these garnets appear smoothly fractured and exhibit no features indicating corrosion.

GLAUCONITE

Glauconite may be very difficult to differentiate from the fine chlorite and other clay paste which is also ordinarily greenish in color. The color of the mineral may vary from brownish green, where considerable oxidation has taken place, to bright green or yellowish green. Under a high-power objective it appears as a mass of minute crystals randomly oriented. In many grains the shape is characteristic, as they are ordinarily rounded, although they may become irregular where the mass has been crushed during consolidation of the sand. In a number of grains a central core of lighter green is surrounded by a narrow, darker zone which shows alteration to hematite and limonite. This darker zone may in turn be surrounded by dark green, more crystalline glauconite, indicating enlargement. Some of the glauconite appears almost "oölitic" in that it may form around other minerals, such as a chlorite grain or a muscovite grain; each nucleus seems to be

a micaceous-type mineral. A deeper green variety of glauconite is found in some of the cores from the lower part of the formation, but it is not certain whether this is characteristic of the formation as a whole.

As already indicated, several generations of glauconite are found, although it is an unstable and soft mineral. Some of it apparently was deposited at the time of the deposition of the Bethel sand and some is definitely of earlier formation, but because of its softness it could not have suffered great transportation unless protected by a harder armor. Good proof exists of at least one earlier period of formation in the case of a glauconite grain which was formed and armored by secondary silica prior to a period of erosion, rounding, and redeposition. Again there was a period of secondary silica enlargement, followed by a period of erosion and rounding prior to deposition in the Bethel sands. A small rim of silica clearly marks the third period of enlargement which has taken place since Bethel deposition.

IRON OXIDES

Hematite-limonite.—These oxides of iron are everywhere secondary and are found as red or yellow stains associated with almost any iron-bearing mineral. Hematite is also found associated with many of the quartz grains but rarely with the feldspar. The hematite on the surface of the quartz grains occurs as small stains in pits, such as on a frosted grain, and the stain is thus preserved from abrasion in the same manner as the hematite stains which occur along cracks and fractures in the quartz particles. In all grains the hematite residues are surrounded by at least one zone, some by two zones, of silica enlargement. A few grains were almost surrounded by a red coating. Great care was taken to make certain that this red coating was not the result of oxidation of clay attached to the surface of the sand grains at the time of their deposition in the Bethel sandstone, as such finely divided clay deposited with the Bethel would be readily oxidized. Any oxidation of Bethel clay is very slight and the original clay can still be plainly seen.

Oxidation to hematite and limonite is found as light coatings on chlorite, glauconite, biotite, leucoxene, epidote, magnetite, and along some of the cleavage planes of the carbonate. Some of the oxidation certainly took place prior to the period of quartz enlargement, inasmuch as parts of the included clay and chlorite show oxidation under the enlargement. Some of it is post-carbonate and post-quartz enlargement in age. Oxidation by ground water has doubtless continued since deposition.

A few minute, rather irregular, opaque inclusions that appear distinctly red-brown in reflected light are found deep within some of the original quartz grains. Their determination as hematite is open to question.

Ilmenite.—This iron-titanium oxide is an exceedingly abundant heavy mineral and comprises, together with its alteration product, leucoxene, almost the entire content of opaque minerals, as well as most of the heavy minerals. No unaltered

ilmenite grains were observed; all of them are covered with leucoxene which commonly shows some limonite staining. The grains appear to be well rounded. The ilmenite is commonly almost entirely replaced.

Magnetite.—The magnetite may occur as small inclusions in quartz, micas, and other grains, and it probably makes up most of the minute, opaque "dust" found as inclusions in other minerals. However, the greatest percentage occurs as fairly well rounded detrital grains showing a discoloration due to oxidation to hematite or limonite. Magnetite is a scarce detrital mineral.

MICA GROUP

Biotite.—Biotite is distinctly minor in occurrence. Most of the few flakes observed show hematite staining and alteration to chlorite. Some of the fresher biotite is brown to brownish green and contains magnetite inclusions. The more altered grains are greenish in color, and one flake shows progressive alteration from green biotite to chlorite to penninite. Some of the alteration to chlorite doubtless took place prior to deposition, but although proof is lacking, it is believed that a considerable part of it took place after deposition.

Muscovite.—Muscovite is far more commonly found than biotite. It may show iron staining and may contain opaque inclusions, probably magnetite. Like biotite, the plates are larger than the other sand grains, and the typical shape is flat with edges either much frayed and split, or more rarely, well rounded. Several large plates were found caught between sand grains and badly twisted, bent, and broken by compaction of the sand.

Sericite.—Sericite is a fairly abundant mineral but occurs as very fine shreds and plates and not as large flakes. It is found as separate grains, some of which appear to be derived either from recrystallizing clay or from some primary source such as the metamorphic schists which furnished some of the other sediments. Some is also derived from alteration of feldspars, the plagioclase yielding most of it. In a few places sericite was observed to be replacing quartz.

PYRITE

In a few places pyrite was found filling the pores between the grains. No detrital pyrite was found. The relative scarcity of authigenic pyrite is a little strange in that considerable iron is present, and sulphur is present in the petroleum. Possibly the large amount of titanium associated with much of the iron has had a restraining effect upon the formation of pyrite.

PYROXENE GROUP[9]

Like the amphiboles, all the pyroxenes are much altered to green chlorite, and their identification was primarily dependent on some of the less altered cores of the minerals and the relics of cleavage. These grains are extremely scarce. Two

[9] McCartney has found hypersthene in the Chester sandstones of Indiana, but does not indicate in which formation. G. C. McCartney, "A Petrographic Study of the Chester Sandstones of Indiana," *Jour. Sed. Petrology*, Vol. 1 (1931), pp. 82–90.

varieties were tentatively identified as much altered augite and as well rounded enstatite, the latter being less altered than the augite. The augite could equally well be diopside. The enstatite showed parallel extinction and contained numerous inclusions, ordinarily opaque and randomly arranged. The grains appeared non-pleochroic, but due to alteration to some variety of chlorite, possibly antigorite, pleochroism was difficult to observe.

QUARTZ

Quartz is the most abundant of all the minerals and is made up of several varieties. A detailed study of quartz grains will yield in most cases as much information in regard to the origin of the sediment and its history as will a study of the heavy minerals, and without the laborious process of making heavy-mineral concentrates. A study of quartz grains is especially valuable in the study of sediments which are notably lacking in heavy minerals.

The following types of quartz have been identified, and occur with varying degrees of abundance.

1. Clear, inclusion-free quartz
2. Quartz with small irregular-shaped mineral or non-mineral inclusions
   a. Inclusions irregularly distributed
   b. Inclusions in bands
3. High-temperature quartz
4. "Dusty" quartz, or quartz full of small irregular inclusions
5. Quartz with regular-shaped inclusions
6. Quartz with acicular inclusions
7. Metamorphic quartzitic quartz
8. Pegmatitic quartz
9. Mylonitized quartz
10. Pinkish quartz
11. Chert
12. Secondary quartz
    a. Chalcedony
    b. Enlargements

Clear, inclusion-free quartz.—Quartz with no inclusions at all is very rare. Such quartz is typically colorless.

Quartz with small irregular-shaped mineral or non-mineral inclusions.—Most of the quartz grains contain numerous small irregular-shaped inclusions filled with liquid, or more commonly with minute mineral grains. Some of these included mineral grains may contain inclusions themselves. The most common minerals occurring as irregular inclusions are opaque (probably magnetite); chlorite fragments, which may be vermicular in outline or even bent and folded; and rarely, bluish green apatite (?) and tourmaline, both of which have been corroded and rounded.

The foregoing inclusions are ordinarily distributed randomly through the grains, but not in great abundance. In some grains the inclusions are drawn out and appear as flow lines. Inclusions of the latter type are most likely to be of gas or liquid, or "opaque dust" which is too small to differentiate as gas, liquid, or solid in nature. In other grains the inclusions are definitely in a plane, which possibly represents a fracture in the quartz developed prior to complete consolidation. Healing of the break was accompanied by the development of the irregular in-

clusions. None of the inclusions drawn out in flow lines or found along fracture planes has any semblance of crystal form.

High-temperature quartz.—Some quartz grains show irregular fracturing and also complex twinning, which features probably indicate an original high-

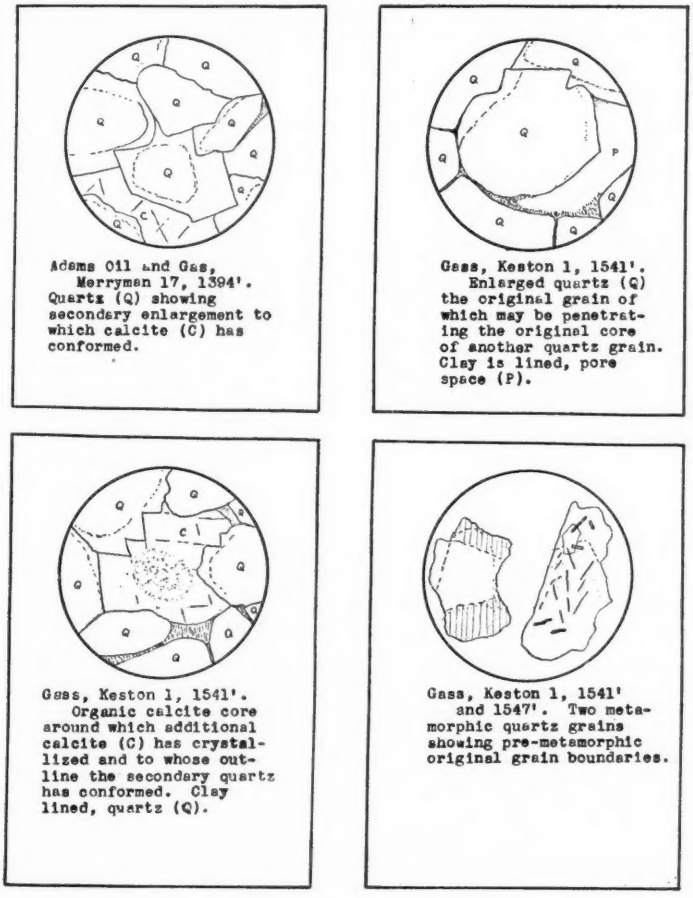

Adams Oil and Gas, Merryman 17, 1394'. Quartz (Q) showing secondary enlargement to which calcite (C) has conformed.
Gass, Keston 1, 1541'. Enlarged quartz (Q) the original grain of which may be penetrating the original core of another quartz grain. Clay is lined, pore space (P).
Gass, Keston 1, 1541'. Organic calcite core around which additional calcite (C) has crystallized and to whose outline the secondary quartz has conformed. Clay lined, quartz (Q).
Gass, Keston 1, 1541' and 1547'. Two metamorphic quartz grains showing pre-metamorphic original grain boundaries.

FIG. 3.—Camera-lucida drawings of grain relationships.

temperature quartz that later inverted to the low-temperature form upon cooling.[10] These grains may contain numerous irregular-shaped inclusions and some regular-shaped ones, but all the inclusions are small and no grain is full of them.

[10] F. E. Wright and E. S. Larsen, "Quartz as a Geologic Thermometer," *Amer. Jour. Sci.*, Vol. 27 (1909), pp. 436–43.

"Dusty" quartz, or quartz full of small irregular inclusions.—"Dusty" quartz is quartz which is full of minute inclusions and probably corresponds in macroscopic specimens with either milky or smoky quartz. There is a sharp increase in number of inclusions between the "dusty" quartz and ordinary quartz containing

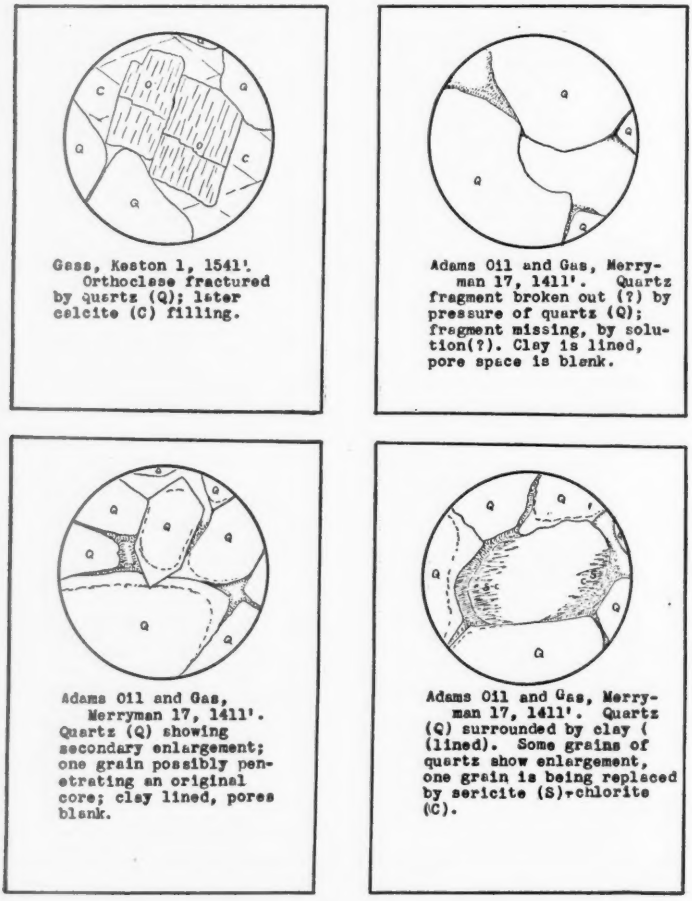

Q
C
Gass, Keston 1, 1541'. Orthoclase fractured by quartz (Q); later calcite (C) filling.
Adams Oil and Gas, Merryman 17, 1411'. Quartz fragment broken out (?) by pressure of quartz (Q); fragment missing, by solution(?). Clay is lined, pore space is blank.
Adams Oil and Gas, Merryman 17, 1411'. Quartz (Q) showing secondary enlargement; one grain possibly penetrating an original core; clay lined, pores blank.
Adams Oil and Gas, Merryman 17, 1411'. Quartz (Q) surrounded by clay ((lined). Some grains of quartz show enlargement, one grain is being replaced by sericite (S)+chlorite (C).

FIG. 4.—Camera-lucida drawings of grain relationships.

irregular inclusions. The inclusions in the "dusty" quartz are all small and very irregular and appear to be made up of opaque minerals, transparent minerals, and liquids or gases. No mineral species can be recognized among the inclusions.

Quartz with regular-shaped inclusions.—Quartz grains containing regular inclusions are fairly common. A quartz grain is placed in this group only if it has

no inclusions of the irregular type, and only if the inclusions are minerals and show a definite crystal form. As a result, many grains classified as of irregular type may also contain regular inclusions. Most of the regular inclusions are prismatic and are either pale blue-green apatite (?) or greenish tourmaline. Some greenish chlorite is present. Its outline is commonly nearly circular or rounded, as might be expected due to its typical pseudo-hexagonal crystallization.

Quartz with acicular inclusions.—Quartz grains with acicular inclusions are very rare, but there are ordinarily a few in each sample. The inclusions are ordinarily either rutile or sillimanite. They may be oriented either parallel with each other or set at all angles. In some cases, they cut across grain boundaries of metamorphic quartzite aggregates. One characteristic of these grains is that they do not show strain shadows, as though reorganization of the quartz has taken place and relieved all strain.

Metamorphic quartzitic quartz.—The metamorphic quartzitic quartz consists of several original quartz grains grown together to form a compact aggregate, and then the whole aggregate eroded and deposited as a unit. In these instances, the contacts between the original grains are gently sutured, and the grains may fade one into the other. Rarely can original boundaries be recognized other than by the optical orientation of the individual grains of the aggregate. Most of the aggregates are remarkably free from impurities.

In a few cases, the outlines of pre-metamorphic quartz grains can be determined. These pre-metamorphic grains appear to have been fairly well rounded, although metamorphism doubtless has reduced some of the angularity. There is no evidence of more than one period of erosion and deposition since metamorphism, at least none in environments which promoted secondary silica enlargement. The aggregates show a high degree of rounding.

One of the best examples of a pre-metamorphic quartz grain consisted of an old rounded quartz core enlarged secondarily by the development of a pyramid on one end. Two other quartz grains penetrated this pyramid. All three grains were tied together with interpenetrating acicular and prismatic inclusions which developed during a period of metamorphism. This period was followed by rounding and deposition, and then enlargement of the whole unit in the Bethel sandstone. A second similar unit was found, but instead of acicular inclusions tying the grains together, a small string of inclusions cut across the original grain boundaries and enlargements. One unit was found in which a rounded quartz grain appeared to have been twice enlarged prior to metamorphism, at which time a muscovite flake developed, cutting across the original grain and the two enlargements. This unit was rounded and deposited and then re-enlarged in the Bethel sandstone.

Pegmatitic quartz.—Several types of grains have been found which belong to the pegmatite variety of quartz. The most common of these are grains full of relatively large inclusions dominantly made up of greenish chlorite with considerable amounts of tourmaline and apatite, and with many cavities filled with liquid, gas, or both liquid and gas, as well as with magnetite dust, spinel, and other

minerals. The chlorite may be vermicular in outline, rounded, or otherwise irregular, and commonly is sharply bent. The tourmaline occurs as stubby blue-gray or olive-green prisms, or as elongate bright green prisms. The latter are rare. The apatite is pale greenish blue and prismatic, although it may be somewhat rounded. Other minerals occur in various shapes, some of the magnetite(?) appearing as short needles, which under high power are seen to be made up of minute strings of grains. Liquid inclusions, with associated gas, have been observed in this type.

A second very common type of pegmatite grain occurs as a piece of quartz full of large, irregular chlorite, and a third type consists of a micrographic intergrowth of orthoclase and quartz. The orthoclase may be altered and both may contain inclusions. This type is very rare and only a few grains were found.

Mylonitized quartz.—The mylonitized type of quartz is comparatively rare and consists of a metamorphic aggregate which has been crushed, and the grains evenly rounded. All members of the unit extinguish differently, and their contacts are not sharp. Some grains are partly crushed along one side, and a larger grain or group of grains remains associated with the finer ones. All these units have been rounded and enlarged during the present cycle. There is no evidence of an earlier post-metamorphic cycle of erosion yielding silica enlargement, but some of the grains still show hematite cement in pits, indicating a post-metamorphic period of deposition in redbeds, or in a deeply weathered red soil. There is no proof that these grains are from a metasediment rather than from a metamorphosed igneous mass. The apparent moderate angularity and sphericity of the coarser grains may be only the result of the crushing. Some of the units have almost a "mortar structure."

It should be noted that all of the distinctly metamorphic grains are much freer from inclusions than the rest of the quartz, which may or may not be metamorphic in origin. Also, the few inclusions found in these grains seem to be more euhedral than in the other quartz grains, and are prismatic or acicular.

Pinkish quartz.—Only one grain of pink quartz was found. It appears to be a very rare type. The color is not due to surficial discoloration.

Chert.—Chert is abundant and there are ordinarily several grains in every sample. It normally is gray but a few reddish pieces were observed. It is distinctive in that it does not show secondary enlargement. It is uniformly very well rounded and without exception has a high sphericity. There is no evidence of any distortion or of conformation to other grain boundaries.

Secondary quartz.—Secondary quartz may exist as chalcedony. This apparently was deposited between the sand grains by ground water after secondary enlargement of all grains. There is no evidence of connection between the secondary quartz enlargement and the interstitial chalcedony, nor any evidence of enlargements of quartz by chalcedony. It is ordinarily colorless, although it may contain some hematite which colors it red.

Considerable data regarding secondary quartz enlargement have been given in the discussion of other minerals and varieties of quartz. The enlargement may

either be clear or may contain inclusions; it may be colorless, but commonly is somewhat yellow. Pyramids ordinarily form if space is available, and pyramids will preferentially penetrate enlarging prisms of adjacent grains. The growth is typically in optical continuity with the core of the grain and in the same crystallographic direction, although grains have been found in which it is at an angle. This growth is remarkably illustrated in a piece of strained quartz which has been enlarged during Bethel sedimentation. The enlargement has carried out the same strain pattern that is found in the quartz core.

All quartz grains show a uniformly high degree of rounding and relatively high sphericity, although here and there one shows fracture and breakage. Because of the secondary enlargement, it is difficult to demonstrate that there may not be two or more groups of grains with different degrees of rounding and sphericity and thus having different origins and histories, but this is certainly not apparent.

Enlargement of quartz has thrown light on a number of interesting features of earlier cycles of sedimentation. One of the most notable is the common fracturing and breaking of the quartz, presumably during compaction in an older sediment since the fragment and grain would be separated had it occurred during a period of transportation. Many of the fragments are twisted, but due to their structure or shape, the way they fitted together can readily be determined. These fragments were then cemented together by secondary quartz and later were redeposited as a rounded aggregate in the Bethel sands.

Although all quartz grains appear equally susceptible to replacement, the secondary enlargements may be a little more so. The quartz may be replaced by calcite, sericite, or chlorite. One grain was found which showed a pure quartz core with one end altered to chalcedony or a very fine aggregate of silica, and this in turn replaced by penninite, indicating an intermediate step in the replacement process. Where quartz has been replaced by sericite or chlorite, the quartz is adjacent to a mass of clay. This may indicate that the elements needed for the replacing minerals were extracted from the clay.

Some quartz replacement occurred prior to the present period of deposition, as both chlorite and sericite are found replacing quartz, and the whole unit has been rounded. In one grain showing chlorite replacement, the quartz contained acicular inclusions, possibly indicating a low-temperature metamorphic origin for the unit.

Several interesting grains were found which indicate primary periods of growth of the quartz. In some of these, an angular core may exist and be surrounded by a thick outer shell, which shell may be many times wider than the original core, and may or may not be oriented in the same way. One interesting example was seen in a quartz core which was full of numerous irregular and elongate prismatic inclusions. Along the outer edge of the inner core was a strong concentration of inclusions. An intermediate zone contained inclusions of much the same type as the core, but in decidedly less quantity. The outer two zones extinguished at the same position, but the inner zone at a different position.

A considerable part of the quartz shows strain. Part of this may be due to metamorphic effects and part due to stresses set up during compaction of the sand. If metamorphism is strong enough, the quartz recrystallizes and loses its strain shadows.

The presence of hematite on or in the grains has been discussed in detail under "hematite." It is of interest that the grains of definite metamorphic origin rarely show hematite coatings whereas the other grains may commonly show it. However, since the proportion of the definite metamorphic-type grains to the other inclusion-rich varieties is very low, this observation is perhaps not to be considered diagnostic.

SILLIMANITE[11]

Sillimanite (?) is found only as acicular inclusions in some of the quartz grains. The fibers are not oriented in any particular direction either to each other or to the quartz grain and are so small that they are difficult to differentiate from rutile needles, some of which occur in the same fashion. However, where best developed they may show good cross-fracturing and a relief definitely less than that of rutile.

SPINEL

Spinel is very rare but has been found as inclusions in quartz and as detrital grains. It is a green variety, probably close to pleonaste. One detrital grain was euhedral with all corners sharp and there was no evidence of corrosion or abrasion. Doubtless it occurred as an inclusion in quartz and was released just prior to deposition. Two other detrital grains of green spinel were well rounded.

STAUROLITE

Only one grain of staurolite (?) was observed and this occurred as a yellow-brown inclusion in a piece of strained quartz.

TITANIUM MINERALS

Titanium oxides.—Of the titanium-bearing minerals in the sand, ilmenite (which has been described under "iron oxides"), leucoxene, and rutile are the most abundant.

Leucoxene is a white, opaque, amorphous alteration product of ilmenite, although commonly it is stained yellowish from iron oxides. Some of the leucoxene grains have no ilmenite core, but are entirely made up of compact, well rounded aggregates that probably are detrital in origin, rather than formed in place. The more irregular and less compact grains may be authigenic.

Rutile is not abundant in any form. It may occur as orange-brown to deep

[11] McCartney has found the closely related dynamo-metamorphic mineral kyanite in the Chester sandstones of Indiana, but does not indicate in which formation. McCartney, *op. cit.*, pp. 82–90.

red-brown,[12] well rounded, detrital grains. Some of the hair-like acicular radiating crystals in the metamorphic quartz grains may be rutile. Determination of the latter is entirely on the basis of form, as no optical data could be secured.

The other oxides of titanium—anatase and brookite—have been identified in Chester sands.[13] In the present investigation there was no good evidence of either rutile, anatase, or brookite being associated with leucoxene. A few minute grains of what may be anatase and rutile were found associated with leucoxene but the determination is open to question. Also, some of the leucoxene appeared somewhat transparent and colorless, as though the core were possibly brookite or anatase.

Sphene.—Sphene is a calcium titanium silicate, and the one grain found was a perfectly euhedral disphenoid showing no abrasion of the edges. It was brownish yellow and faintly pleochroic. Evidently the grain either had been recently freed from being an inclusion, as is shown by the complete lack of wear, or it is authigenic.

TOPAZ

Topaz occurs as moderately well rounded colorless grains which may be fractured. They ordinarily contain small, dark inclusions bearing no relation to the crystallographic properties of the grain. Topaz is a very rare mineral.

TOURMALINE

On the basis of color, the tourmaline minerals have been divided into the following varieties: (1) olive-green, (2) deep green to brown, (3) red, (4) blue-gray, (5) blue-green, (6) pale blue and dark blue, and (7) black.

The olive-green tourmaline is the most abundant detrital variety and occurs as coarse grains. Rarely do the grains show any inclusions. They are generally well rounded, but may be angular as though recently fractured. This is not surprising as tourmaline possesses a good cross-fracture, which appears in many of the rounded grains. Here and there a grain of the olive-green variety is seen as an inclusion in quartz.

The deep green to brown variety is very similar in all characteristics to the olive-green variety. It is free of inclusions and is rounded, although it may show recent fracturing. This variety is comparatively rare.

Reddish tourmaline is very rare and occurs entirely as small inclusions in quartz. The quartz is ordinarily of the pegmatitic variety.

Blue-gray and blue-green tourmaline is largely confined to quartz inclusions, although the blue-green variety may occur as a detrital mineral. The blue-gray variety is stubbier than the blue-green type. Both may show minute inclusions.

[12] McCartney has found that the light-colored grains are an earlier stage of the development of rutile from leucoxene, and that the deep red rutile is that which has thoroughly changed from leucoxene and has already passed through the light-colored stage. *Ibid.*, p. 86.

[13] *Ibid.*, pp. 82–90.

Tourmaline of a deeper blue than either of the foregoing was found as a quartz inclusion. In the center of the blue tourmaline was a large, euhedral, deep blue tourmaline crystal oriented in the same direction as the outer paler blue shell.

The black tourmaline was found in only two samples. Where present, it is jet black and the grains are nearly perfectly spherical, being much better rounded than any of the other varieties.

That some of the grains have gone through a previous cycle of erosion and deposition is seen in a green tourmaline crystal which was fractured and cemented together so that the two parts are at an angle. The two units were later rounded, prior to their present deposition. None of the tourmaline shows evidence of secondary enlargement.

ZIRCON

Based on color, the following zircon varieties have been recognized: (1) white, (2) gray and bluish gray, (3) yellow to yellow-brown, (4) pink to red, and (5) brown to reddish brown.

The inclusion-free, colorless variety is ordinarily angular and in places still shows crystal faces, although it may be somewhat rounded; however, one almost perfectly spherical, colorless, inclusion-free grain was found. The colorless variety which shows inclusions is commonly well rounded. The inclusions in the zircon grains may be acicular, elongate prismatic, or may be made up of transparent and opaque "dust." The inclusions may be zoned in the crystal, and one well rounded zircon shows a darker subhedral core. Both colorless types are comparatively rare. Gray to bluish gray varieties are rare but are fairly well rounded. They may or may not contain euhedral inclusions. All yellow to yellowish brown varieties are well rounded, and together with the colorless type form the majority of the zircons. A faintly pink zircon was found as a euhedral inclusion in quartz, but most of the detrital red grains are mediumly well rounded. The brown to reddish brown variety without exception shows well rounded grains and may contain small inclusions of both opaque and transparent minerals. A single well rounded brownish green grain was also found. Evidence of earlier cycles of sedimentation are lacking except for the extreme degree of rounding of some of the zircon varieties, as contrasted with the poor degree of rounding of other varieties.

MINERAL AGGREGATES

Only three types of aggregates occur. (1) The quartz aggregates have been described under "quartz." (2) The clay aggregates which have been mentioned under the "clay minerals" represent shale fragments and are made up of a variety of minerals such as quartz, chlorite, sericite, clay minerals, and other hydrous silicates of a size less than 1/256 mm. in diameter. The coarser aggregates are dark greenish gray shale. Although made up of an aggregate of fine minerals, they react like a single mineral. They may show crushing and squeezing in such a manner that they conform to the outline of the coarser, tougher, detrital min-

erals. (3) The schist (?) aggregates were found only as a few grains and were composed of an intergrowth or replacement of quartz by chlorite and sericite. These aggregates should not be confused with the Bethel replacements of quartz which, unlike the schists, do not show any pre-Bethel period of erosion and enlargement.

INCLUSIONS

Almost any mineral may contain inclusions, and even the inclusions may in turn contain inclusions. Inclusions may be either opaque or transparent minerals, liquid or gas, or combinations; they may be euhedral or anhedral, rare or abundant. Most of the inclusions are very small, being but a few thousandths of a millimeter in size; they average about 0.002 mm. across; the inclusions within the foregoing inclusions are correspondingly minute.

The inclusions may be arranged parallel with crystallographic directions of the grain in which they are found, they may be zoned, or more commonly they may be irregularly scattered through the grains. They may be confined to a central core or may cut across the core and enlargements into adjacent grains. Inclusions of chlorite and clay material commonly mark the boundaries of original grains; the enlarging material rarely shoves the clay away. The enlargement may be clear or contain inclusions. Where there is any parallelism of inclusions, they are ordinarily concentrated along a fracture or cleavage plane of the mineral, or along flow lines formed during the last stages of consolidation of the including grain.

The following minerals were observed to contain inclusions: apatite, calcite, chlorite, cordierite, epidote, orthoclase, microcline, plagioclase, muscovite and sericite, biotite, enstatite, quartz, tourmaline, and zircon.

The following minerals were identified as inclusions: apatite, chlorite, magnetite, ilmenite, hematite, muscovite or sericite, sillimanite, spinel, staurolite, rutile, tourmaline, and zircon. In addition there were numerous inclusions too small to be identified.

WATER-SOLUBLE MINERALS

Sixteen samples from nine wells scattered uniformly over the basin were selected, and a small chip from the interior of each core was crushed and placed in distilled water. Some contamination from the drilling mud was unavoidable, but it was hoped that this would be reduced to a minimum by using interior pieces of the core. After one hour a drop of water from each sample was placed on a slide and examined under the microscope while it evaporated to dryness. The residue was then covered with cedar oil, or other index liquids, so that the indices of refraction and other optical properties of the crystals could be determined. The same procedure was followed 24 hours later and again a week later. The water and samples were kept at room temperature during the complete investigation.

By the end of one hour all water samples showed small amounts of halite (NaCl). One sample showed some gypsum ($CaSO_4 \cdot 2H_2O$). After 24 hours there

was an increase in the quantity of halite. Also present were minute amounts of an isometric crystal having an index well below 1.54. This possibly represents sylvite (KCl) or a complex sodium-magnesium-potassium salt. In one sample were found a few small hexagonal plates, with an index greater than 1.54. These probably were chloromagnesite ($MgCl_2$).

After leaching the crushed chips for one week, there was found an increase in the variety of minerals present, although halite and chloromagnesite (?) were the only ones that showed a marked increase. These two are relatively abundant; sylvite (?) is relatively rare. In a few cores, minute traces of carbonate were found. Gypsum was present in a few samples, but in very minor quantity. An anisotropic mineral with an index of about 1.60, which crystallized as wedges along the edge of the drops, was found in some samples. Its identity is questionable, but tentatively it is called hydrophilite ($CaCl_2$). This is a relatively soluble mineral, but it did not appear in any of the earlier analyses.

TABLE III
BETHEL OIL-WELL BRINE ANALYSES*

	Well						
	37	40	41	6	38	39	42
Constituents							
Na and K	19,797.1	34,570.0	31,360.3	19,441.0	30,674.0	39,662.8	20,816.7
Ca	971.8	3,513.0	2,577.0	1,975.0	3,922.0	5,174.0	1,552.5
Mg	657.8	1,127.0	1,171.0	613.0	1,088.0	1,523.0	783.0
SiO_2	16.0	120.0	11.0	2.0	0.0	7.0	4.0
Fe	6.8	225.0	1.4	4.0	1.0	24.0	0.0
Al_2O_3	6.4	240.0	20.0	40.0	56.0	16.3	28.0
SO_4	643.6	198.0	9.9	58.0	356.0	60.0	395.1
Cl	33,654.3	62,610.0	56,330.0	35,293.0	57,052.0	74,686.3	36,821.3
HCO_3	158.6	125.0	119.6	93.0	132.0	30.5	119.2
Others	43.8	1,178.0	511.8	2,284.0	701.0	2,632.1	60.7
Total	55,956.2	103,906.0	92,112.0	59,803.0	93,982.0	123,816.0	60,580.5
Hypothetical Combinations							
NaCl	50,323.7	87,889.0	79,706.7	49,415.0	77,966.0	100,820.2	52,014.1
$MgCl_2$	2,576.2	4,414.0	4,588.7	2,400.0	4,257.0	5,962.0	3,066.7
$MgSO_4$	.....	.....	.....	.....	.....	.....	.....
$CaCl_2$	1,804.7	9,400.0	7,015.6	5,286.0	10,335.0	14,233.0	3,735.4
$CaSO_4$	911.1	280.0	14.3	82.0	505.0	85.1	559.4
$CaCO_3$	130.0	103.0	98.0	76.0	108.0	25.0	97.7
SiO_2	16.0	120.0	11.0	2.0	.....	7.0	4.0
Fe_2O_3	0.6	324.0	2.0	6.0	1.0	5.7	0.0
Al_2O_3	6.4	240.0	20.0	40.0	56.0	16.3	28.0
Others	96.3	96.0	150.9	359.0	28.0	17.0	119.9
Total	55,865.0	102,869.0	91,607.2	57,666.0	93,256.0	121,171.3	60,525.2

* Data from the Illinois State Geological Survey, O. W. Rees, analyst. Constituents and hypothetical combinations all reported in parts per million. Number of well refers to its location in Figure 1.

6. Kesl-Fox, Storer 2, Sec. 13, T. 1 N., R. 1 W., Clinton County.
37. National Pet. Co., Spindler A-4, Sec. 10, T. 6 N., R. 2 W., Bond County; brine from tank receiving oil from wells 1–8.
38. The Carter Oil Co., Tate 1, Sec. 10, T. 1 S., R. 2 E., Jefferson County.
39. Obering and Phillips, Howe 1, Sec. 25, T. 2 S., R. 1 E., Jefferson County; collected from storage tank.
40. Adams Oil and Gas, Merryman 1, Sec. 21, T. 4 N., R. 1 E., Marion County.
41. Shell Pet. Corp., Lutz 1, Sec. 18, T. 3 N., R. 1 E., Marion County.
42. Shell Pet. Corp., Holston lease, Sec. 15, T. 3 S., R. 3 W., Washington County; collected from storage tank.

Table III gives a series of Bethel sandstone brine analyses which were made by the Illinois State Geological Survey, together with the hypothetical minerals that these constituents form. It is noted that halite, chloromagnesite, and hydrophilite

are the most abundant theoretical minerals, and that gypsum and the other minerals are relatively rare. Hydrophilite is the one theoretical mineral which was not abundant in the microscopic examination, or else it was not positively identified.

Some of the samples were saturated with oil and some were unsaturated. The saturated samples showed, even after one week, only negligible amounts of halite and sylvite (?), probably because the oil prevented their going into solution. However, when the oil was washed out with carbon tetrachloride, the same samples showed a marked increase in the minerals taken into solution.

VARIATIONS LATERALLY AND VERTICALLY IN MINERALOGY

The mineralogy appears to be very uniform in the area studied with no appreciable change either laterally or vertically. Data are insufficient to show whether or not the mineralogy varies with structure.

PETROGRAPHIC DESCRIPTION OF THE BETHEL SANDSTONE

The sandstone of the Bethel formation is fine-grained and typically varies in color from white to brownish, but where it is argillaceous it is gray or light green. At some places the sandstone is massive, at other places it is thinly and evenly bedded and contains numerous partings of green micaceous shale. The bedding may be horizontal and parallel but more commonly it is irregular, wavy, or cross-bedded. Most sand units more than ½ inch thick show some kind of bedding, even though it is almost microscopic.

Generally the sandstone is poorly to well cemented with silica, but in places there are calcareous lenses. Where the sandstone is well cemented, its color is ordinarily lighter than where it is uncemented. The strictly arenaceous part appears to be non-fossiliferous, but under the microscope some fossil remains can be recognized; ordinarily these have been largely recrystallized to form calcareous cement. The calcareous and argillaceous part of the formation contain some fossils—primarily crinoids and brachiopods.

Shale in the formation may be paper-thin breaks or may be beds ranging from a fraction of an inch to several feet in thickness. The shale is greenish, in places silty, and contains abundant fine sericite or white mica flakes deposited parallel with the bedding. These give the shale, especially that found along the sandstone bedding planes, a noticeable sheen when split parallel with these planes. Dark mica and carbonaceous material may also be present. In general the contact of the shale with the sand is relatively sharp. In many places the shale is merely a lens in the sand, or if the core is dominantly shale, the sand may be a small sand lens in the shale. In the former case when the shale lens is about the size of a small button and is set at an angle to the bedding-plane, or otherwise obviously was not formed *in situ*, it is considered to be an original shale fragment which has acted hydraulically similar to the finer-sized sand grains because of its much greater surface area. In the latter case the sand is fine, very clean, well cemented, and makes a more gradual contact with the shale.

Near the base of the Bethel formation, limestone and shale pebbles are found, although shale pebbles may be found throughout the formation. In the southwest part of the state, small limestone fragments are abundant in some lenses, and Weller and Sutton[14] have reported small quartz pebbles in the Bethel formation along its southern line of outcrop. However, within the Bethel sandstone beds in the upper part of the formation in the area covered by this paper, there is no evidence of any local conglomerates, although in some places slightly coarser quartz aggregates, clay pellets, and shale fragments are present.

In almost all of the thin sections and polished sections there is good evidence of a definite fabric or pattern in the arrangement of the sand grains. Ordinarily, if there is much elongation of the sand grains, these grains are laid down so that their longest dimension is roughly parallel with the bedding-planes. This is particularly true of the micas and more platy minerals, or of minerals with a good cleavage in one direction.

TEXTURE

Grain size.—The methods employed in making the grain-size analyses have been described in detail elsewhere.[15] Briefly the methods employed consist of first brushing from a freshly broken surface of a core "biscuit" a representative sample of the sand grains. These are mounted on a slide, in a mixture of $\frac{1}{3}$ water and $\frac{2}{3}$ glycerine, and projected downward upon a white table top. Magnification depends on the grain size. A representative field containing approximately 50 grains is selected and marked out. All of the grains within this representative field are measured for size and shape. The size of the grains is measured by the length of the shortest diameter of the projected grain image (b-axis). The numerical frequency of the different sizes is determined, and by knowing the magnification, the corresponding numerical phi-frequency distribution can be determined. Although all the statistical manipulations can be applied to numerical frequency data, the numerical data can not be converted directly into weight data. However, as long as one system is used throughout the entire investigation, all the data can be compared and correlated.

An examination of a representative sample of grains under a microscope indicates that although there is a rapid decrease in frequency of occurrence of grains finer than the mean until a grain diameter of approximately 0.02 mm. is reached, the frequency then rapidly increases to a sharp maximum for the still finer-grade sizes. For numerical counts this maximum might even approach or exceed the maximum in the coarser grades, but it would be practically negligible in a weight analysis.

Systematically throughout the analysis of the Bethel sandstone any residues finer than 0.01 mm. were ignored. This procedure was followed because their

[14] Weller and Sutton, *op. cit.*, pp. 823–28.

[15] W. D. Pye, "Rapid Methods of Making Sedimentational Analyses of Arenaceous Sediments," *Jour. Sed. Petrology*. Vol. 13 (1943), pp. 85–104.

abundance in some slides is due to several causes. They may have come (1) from the thin shale bands and lenses marking bedding planes and thus involve a mixing of sediment units, (2) from shale granules and fragments which hydraulically act similar to finer sand grains but upon analysis are broken down to their individual grain components, (3) from clay that adhered to the sand grains either during earlier periods of deposition or during their last period of transportation, (4) from fracture fragments or cleavage flakes broken off the original sand grains, (5) from mafic minerals which were badly altered and decomposed either prior to or after deposition, and which on analysis break down from coarse grains to a multitude of fine clay or chlorite flakes, and (6) from fragments from the secondary cement and enlargement of the grains. Of these latter, the carbonate commonly appears as freshly fractured rhombs; the quartz appears (a) as curved shells that fitted around the sand grains, (b) as sharp triangular fragments formed where the enlargement fitted between other sand grains, or (c) as fragments showing part of crystal faces of quartz, especially the pyramids.

Some clay was of course deposited as such, but it is impossible to determine what percentage of the clay found in the projected slide is the result of the preparation of the sample for analysis and what percentage should naturally be present. Another difficulty is that measurement errors increase as the definition of boundaries becomes poorer in the finer grains and the individual grains are more difficult to resolve and separate.

The largest sized grains encountered in the Bethel sandstone were in the 1.0 to 1.5 phi class (0.5 to 0.35 mm. diameter), and the finest measured grains ranged down to 6.0 phi units (0.01 mm. diameter) or less. The means ranged from 2.40 to 4.66 phi units (0.2 to 0.04 mm. diameter), based on numerical frequency, with an average of about 3.50 phi units (0.09 mm. diameter). Most of the means fall between 3.30 and 3.70 numerical phi units (0.10 to 0.08 mm. diameter). Thus, the sand is very fine-grained with a remarkably uniform size distribution over the entire part of the basin studied. In fact, the standard deviation of the size means is 0.41 phi unit.

Sorting.—All of the Bethel sandstone samples examined are extremely well sorted. As a whole, more than 68 per cent of the grain-size distribution falls within less than 1.6 phi units; most of the samples have this amount within 1.0 unit. In the best sorted sand, 68 per cent falls within 0.4 unit, and 99.7 per cent falls within 1.2 units.

More than 25 per cent of the samples have a standard deviation of less than 0.4 unit and more than 66 per cent are under 0.50 unit. Most of the sands have a standard deviation between 0.3 and 0.6 unit. The mean of the standard deviation is 0.47 and its standard deviation is 0.19.

Shape.—The shape of the sand grains was determined by measuring the short diameter of the sand-grain image (this is the b-axis or the same diameter as was used to give the size of the grain) and the long diameter (a-axis) of the image at right angles, or essentially so, to the short diameter. The shape is then given by

the ratio of the square root of the short and long diameters. The more spherical the grain, the nearer to unity is this ratio.[16]

The sphericity of the grains of all the minerals except the micas is uniformly high. Feldspars ordinarily form equant-shaped grains; zircon, tourmaline, and apatite, among others, are elongate in the direction of the prisms. If the quartz shows any elongation, it is commonly parallel with the prism. Quartz fracturing seems to be developed along partings parallel with the pyramid faces, and these may produce somewhat elongate grains.

The uniformly high sphericity is especially notable in the quartz and other grains which lack cleavage and are essentially uniform in hardness in all directions. In all cases the mean of the measured shape of quartz ranged between 0.8 and 0.9 and extreme shape values of individual grains ranged from 0.6 to 1.0. The other minerals were not in sufficient quantity to warrant applying other than qualitative studies of shape. The grains with low sphericity evidently had suffered recent fracturing. Some of this fracturing apparently came from the transportation processes, some occurred during compaction of the sand and some undoubtedly came from disaggregation at the time of mounting the grains. It is believed that the measured sphericities are correct in that qualitative studies of sphericity by observation under the microscope gave equally high values. Thus, the sands of the Bethel have a uniformly high sphericity in the basin studied.

Roundness.—Roundness determinations were made by visually comparing the outline of either the projected image, or the outline of the grains mounted in oil under the microscope, with a roundness chart.[17]

As determined visually under the microscope, the roundness of the original Bethel sand grains is high, ranging from 0.4 to 0.7. The average is probably close to 0.6. However, it must be remembered that this roundness is determined from those small parts of the original grain which are distinguishable from the secondary enlargement, rather than from the complete grain. All the grains appear to have a very uniform high roundness, except the rare grains that have suffered recent fracturing and insufficient transportation to re-round them.

Not only are the grains which have undergone one cycle of erosion and deposition well rounded, but the fragments of grains which have undergone two or more cycles appear to show that during each period of erosion and deposition the grains were well rounded. The latter grains are so few, and parts showing more than one period of erosion are so small, that it is difficult to determine whether the grains of the last cycle were more rounded than were the grains of older cycles. In a few cases the older ones appear a little more angular, but in most cases they appear equally well rounded.

Surface.—The surface of most of the grains is concealed by the secondary

[16] W. D. Pye and M. H. Pye, "Sphericity Determinations of Pebbles and Sand Grains," *Jour. Sed. Petrology*, Vol. 13 (1943), pp. 28–34.

[17] W. C. Krumbein, "Measurement and Geological Significance of Shape and Roundness of Sedimentary Particles," *Jour. Sed. Petrology*, Vol. 11 (1941), Pl. I, p. 68.

enlargement, but in some grains where the surfaces are observable they are either (1) very smooth, although not actually polished, or (2) pitted and frosted. The latter type of grain is common, and much of the hematite associated with the quartz grains is found in the pits.

Fabric.—The fabric of the rock is described later in connection with its bearing on porosity, permeability, and oil recovery. It may be stated briefly here that in most cases elongate grains tend to be oriented so that their maximum elongation is parallel with the bedding planes. The maximum area of grains of platy minerals is parallel with the bedding. This is so marked that ordinarily the direction of bedding can be determined simply by an examination of the grain orientation. On the other hand, some of the small platy shale fragments may lie not parallel with, but somewhat inclined to the bedding.

Although roundness and sphericity of the grains are comparatively high, yet the size distribution is such that there is no systematic packing of the grains—instead the arrangement is entirely random.

VERTICAL AND LATERAL VARIATIONS IN BETHEL SANDSTONE AND INTER-RELATIONSHIPS OF PARAMETERS

Sampling of the Bethel sandstone in the subsurface is entirely dependent on the collection of cores from wells, which are generally drilled on structures or adjacent to oil production, and as the sandstone may not be cored unless oil-saturation is noted in the cutting returns or is expected, there results a large field-sampling error. In fact, more than three-fourths of the cores available in the area under study were partially saturated with oil. As a result, there is very little information about the Bethel sandstone in areas where there is no oil production. Because of the large field-sampling error, the apparent vertical and lateral variations in the physical properties of the Bethel sandstone may not be real, and too much weight should not be placed upon these trends in any interpretation. The following analysis of variations is based on cores from only 24 wells.

Size.—In cores from 13 wells the mean size of the Bethel sand grains became progressively coarser, and in cores from 9 wells it became finer with depth. The cores from the other wells showed no distinct trend one way or the other. There is no relationship between the geographic location in the basin and the direction of change in size of the sand with depth.

Areally, there seems to be a little more variation. At a horizon of 5 feet below the top of the sandstone, a progressive shift eastward toward the finer-grade sizes is found in the sand grains. This shift appears to a limited extent in the samples taken from 10 feet below the top. However, there are many irregularities. As is shown in Figure 5, the contours based on size vary irregularly and only general trends should be read from them, as the wells can not be considered as yielding random samples of the Bethel sandstone. Also, the depth of "five" feet or "ten" feet below the top of the sandstone may be incorrect, because picking a formation top is dependent on cutting returns. Furthermore, at some wells, complete re-

covery of cores was not possible or samples at the exact depth were unobtainable. Moreover, if in a number of wells a sample had been selected a few inches above or below the point from which it was selected, a different result might have been obtained.

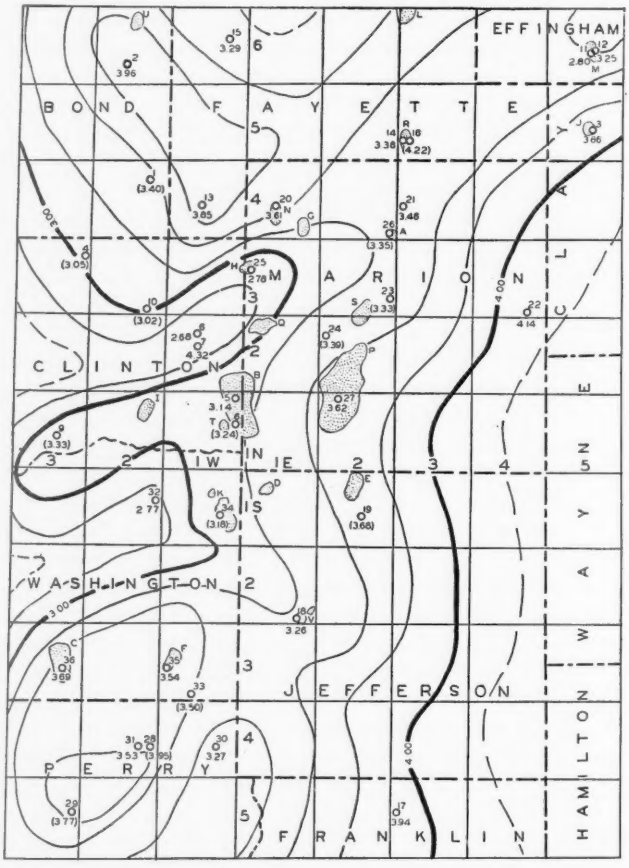


FIG. 5.—Map showing mean size of sand-grain distribution at 10 feet below top of Bethel sandstone.

One other generalization regarding the areal variations in mean size is that there is some evidence of a coarse sand zone trending northeast from central Clinton County. However, as already pointed out, too much stress must not be placed upon these irregularities.

Sorting.—Eleven wells show poorer sorting of the sand with depth and six

show better sorting. There is no correlation between changes in sorting with depth and the location of the well in the area. There is no appreciable variation areally.

Shape.—Ten wells show an increase in sphericity of the sand with depth; only two show a decrease. Again, there is no relationship between the location of these wells and their variations and their position in the basin. Areally, there is little change, but possibly the sand is somewhat more spherical near the center of the area than around the edges.

Roundness.—There seems to be no appreciable variation either vertically or areally in the degree of roundness of the sand.

Size and sorting.—In the area as a whole, most of the sand is found to have a mean size between 3.30 and 3.70 phi units, and a standard deviation between 0.3 and 0.6. The sorting seems to be best in that region which contains most of the means of the size distribution, and the sorting becomes poorer as the size becomes both coarser and finer. Perhaps a mean size of about 3.50 phi units might be called the critical value at which the degree of sorting reaches its maximum.

There is no apparent correlation of changes in size and sorting of the sand with depth or location of the well. However, for individual samples, the ratio of increasing coarseness of the sand and increasing degree of sorting to increasing coarseness and decreasing degree of sorting is found to be 27 to 19.

Size and shape.—Variations in mean size and shape of the sand are so small that there is nothing very definite for the area as a whole. However, a careful analysis reveals the following.

1. For individual samples, the ratio of those samples showing increasing coarseness and greater sphericity to those showing increasing coarseness and lower sphericity is 28 to 12.

2. On the basis of the complete length of the core, seven wells show an increase in mean coarseness with increasing mean sphericity and depth, while only three show an increase in coarseness with decreasing mean sphericity. The other wells show no marked tendency one way or the other, nor is there any correlation between the changes in depth and the location of the well in the area.

3. If mean size is plotted against shape, generalities are even more vague and they must be regarded as only slight tendencies. (1) Sand from samples taken at 5 feet and 10 feet below the top of the Bethel sandstone is somewhat more spherical with increasing fineness up to size means of 3.50 phi units (0.09 mm. diameter). With increasing fineness beyond this value, the samples seem to be less spherical, at least to size means of 4.00 phi units (0.062 mm. diameter). (2) If the mean size and shape of the sand from all samples are compared, there is some slight evidence that the same mean-size value (3.50) still is associated with the most spherical grains—at least the samples of sand with the coarsest and finest means show a lower sphericity, and the samples with intermediate size means show a greater sphericity.

Shape and sorting.—There is no appreciable relationship between shape and

sorting of the sand, other than that if a marked increase in sorting exists, there is a corresponding increase in sphericity. Except in two cases, all samples having a standard deviation of less than 0.48 have a mean-grain sphericity greater than 0.85. With a standard deviation greater than this, or a poorer degree of sorting, the sphericity tends to be less than 0.85. Correlation between the two is not marked unless the changes are pronounced.

Size, shape, and sorting.—Although there seems to be a slight relationship between size and shape, and to some extent between size and sorting, yet between all three any trends in variation are very vague. By comparing successive samples in cores where distinct relationships can be observed, it is found that with increasing mean coarseness of the sand: (1) 20 samples have a greater sphericity and are better sorted; (2) 12 samples have a greater sphericity and are more poorly sorted; (3) 10 samples have a lower sphericity and are better sorted; and (4) 5 samples have a lower sphericity and are more poorly sorted.

The foregoing comparison brings out clearly the fact that there is a relationship between mean size and shape, but that the sorting is a minor factor.

In summary, the highest sphericity and the greatest degree of sorting are ordinarily associated with the mean-grade size of the formation as a whole. Both the sphericity and degree of sorting of the sand decrease as the mean size increases or decreases from this average and as mean size departs from the most common size grade. The only relationship that does not show this trend is between shape and sorting. These show an increasing degree of sorting with increasing sphericity. It may be well to emphasize again that despite the figures and trends given in this discussion, the entire sand body is exceedingly uniform in all of its physical properties, at least as revealed by the cores available for study. Furthermore, as these trends are only poorly indicated, too much weight should not be attached to them.

CLASSIFICATION OF ROCK TYPES OF BETHEL

On the basis of the size, shape, roundness, and mineral-composition analyses, the Bethel sandstone is classified as a very fine-grained sandstone. It is not angular enough to be classified as a grit, nor is there enough non-quartz material to classify the formation as arkose or graywacke. In some of the parts which have considerable carbonate cement, the rock may be termed calcareous sandstone; in some places where it "shales up," it is argillaceous sandstone.

The material with a mean size less than 0.062 mm. in diameter is classified as light buff-colored siltstone in the coarser grades and as green siltstone in the finer green-colored grades. Depending on the color and bedding of the shales, they may be classified: (1) as thin, delicately laminated, and uniformly bedded black and maroon fossiliferous shales, and (2) as massive, arenaceous, and micaceous green shales. Between the shales, siltstones, and sandstones there are all degrees of gradations, but rarely does the rock grade from one to the other; instead, fairly sharp breaks separate materials of markedly different mean-grain sizes.

The variations in physical properties in all directions show that the rock types are remarkably uniform in their characteristics in the part of the basin studied, although there is extensive lensing and lateral gradations of the specific rock types.

Other Sandstones of Chester Series

A few samples were examined from cores in the Cypress, Paint Creek "Stray," and Aux Vases sandstones. The wells and data on the parameters of the sandstones are listed in Table II. From the few samples examined, it was found that so far as shape, sorting, roundness, and mineral species and types are concerned, the sands are identical and could not be differentiated from the Bethel sandstones. Likewise, mineralogically all of the sandstones of the Indiana Chester formations are identical and can not be differentiated one from the other.[18]

In general, the grain size is much the same in the Bethel sandstone as in the other formations. Three samples of Aux Vases sandstone taken from two wells in the north part of the area were coarser than samples of the Bethel sandstone in the same general area but a single sample from a well in the south part of the area indicated that the Aux Vases was nearly the same as, or a little finer-grained than, the Bethel sandstone. One sample of the Paint Creek "Stray" sandstone from one well and five from another well (both wells north of the area) ranged from coarser to finer than adjacent Bethel samples but averaged nearly the same. Two samples of Cypress sandstone from one well in the north part of the area are a little coarser than the Bethel sandstone in the same general locality, but two samples of the Cypress from a well in the south part of the area are nearly the same as, or a little finer than, samples of the Bethel from the same well. One of the Cypress sandstone samples from the north part of the area was different from any of the Bethel sandstone in that it contained abundant carbonaceous material, but other samples from the same region were not noticeably carbonaceous.

From these meager data, it appears that the other sandstones might be finer-grained southwestward, following somewhat the same tendency as the Bethel sandstone.

In conclusion, the results of the few isolated samples studied show that the Bethel is similar to the other Chester sandstones. The only real difference is in grain size, and this difference is not marked. Too much emphasis should not be laid upon the results of these few scattered analyses of the other sands, as an adjacent well, or a sample from the core higher or lower than the one chosen, might have shown quite different results. The data are too meager to warrant drawing any far-reaching conclusions.

Cements, Their Origin and Age

The Bethel sandstone cement is dominantly silica, with subsidiary amounts of carbonate. Most of the silica cement is present as secondary enlargements of quartz grains and is deposited in optical continuity with the original grain. It

[18] G. C. McCartney, *op. cit.*, pp. 82–90.

may also be deposited in the form of a thin film around clay, glauconite, feldspar, and heavy minerals, although it is nowhere found around chert. Silica cement may or may not fill the space between the grains. In the former case, the sand is tight and non-porous; in the latter, it is loose, poorly cemented, and porous, unless there is excessive associated clay or other materials which have filled the pores.

In general, the secondary silica growth is uniformly distributed among the quartz grains throughout the formation both horizontally and vertically. The cement is typically clear, but in many places tinged, probably by iron compounds, slightly more yellow than the original quartz grains. In certain grains the enlargement is full of inclusions which appear to have been original interstitial clay that has been surrounded and incorporated by the enlargement. In rare cases, the inclusions are liquid, but whether the liquid is oil or water could not be determined.

A transition between the inclusion-free and inclusion-rich enlargements is seen in numerous grains where the clay material has been concentrated between the original grain and the enlargement envelope. In one or two grains, the clay band was seen to pass from the position next to the original grain, through the secondary enlargement, and then out into the inter-grain spaces.

Except in certain deep cores, there is no evidence of extensive cementation by carbonate. Where carbonate is present as a cement, the sand is ordinarily tight and impervious, but these areas are local and apparently are dependent on the presence of some original carbonate in the sediment. There is no uniform distribution of carbonate, except that it may become abundant in certain calcareous lenses. In all cases it is clear and apparently is almost pure calcite except for organic impurities, although in one instance it appeared a little dolomitic. A little iron-staining may be detected along the cleavage planes.

ORIGIN OF CEMENTS

SILICA

The origin of the silica cement is questionable. However, as the total secondary silica deposited on the sand grains is estimated as not exceeding 5 or 10 per cent of the entire rock volume, the volume is not great; therefore, it is not necessary to account for a large source. Possible sources are (1) solution of quartz and silicates, (2) deposition from sea water, (3) deposition from connate water, and (4) deposition from meteoric water or circulating connate waters from other beds.

In regard to solution of silica-bearing minerals, there are several possibilities. The most obvious source is the solution of quartz itself. It is well known that if pressure is applied on a certain area, there is a tendency for a reaction to take place in such a way as to relieve this pressure. To relieve pressure arising at the point of contact between two sand grains, breaking may take place, or one or the other or both of the grains may go into solution in the interstitial liquid. If a saturated solution of the liquid exists for these components, the material is redeposited elsewhere upon the grains where they are not in contact and where the pressure is at a minimum. If the grains are of different chemical composition, the

one which is more soluble goes into solution. If the grains are of identical composition, there may be selective solution, depending on the relative solubility of the different crystallographic directions in the mineral grains. Deposition of the material in solution may take place upon the grain which went into solution or upon some other grain. Laboratory data indicate that the dissolved silica is either precipitated upon, and in crystallographic continuity with, a quartz grain, or occasionally it may be deposited around other minerals on clay, but appears not to have been deposited on chert. The locus of deposition depends on the crystallographic directions. In quartz, the pyramid ends tend to be enlarged first; if there is no room for growth of the pyramids, then the prisms are enlarged. If a grain being enlarged on a pyramid comes in contact with a grain being enlarged on a prism, the pyramid penetrates the prism enlargement and preserves its own sharp crystallographic outline.

Although there is abundant evidence of the deposition of secondary quartz, evidence for solution of quartz due to pressure is meager. There is good evidence that pressure has been exerted on the grains, as the feldspars have been broken along cleavages and offset, micas have been bent and broken, and here and there a corner of quartz has been flaked off. Originally the sand grains must have been merely touching in a few places, but as solution progressed due to the pressure on the grains, they should have touched more and more and become more interlocking. It is true that many grains are interlocking, but on close examination it is found that this interlocking is confined to the secondary growths on adjacent grains, or to a secondary growth on one grain and an original core of another grain. Nowhere were interlocking grain cores found. In a few cases, there was some evidence that one core had slightly penetrated the core of another grain. However, this penetration was very slight, and for the number of cases found in proportion to the number of grains examined, it might well have been the result of one grain settling in an original pit in the other grain. In one case there was evidence of possible penetration, but the original boundaries of the grain being penetrated could not be determined, and the apparent penetration may have been entirely due to secondary quartz deposited on the penetrated grain and overlapping around the penetrating grain. Where fragments of quartz were flaked off, there was no evidence of any penetration by solution; the fragment was found either adjacent to the grain from which it was broken or it was recemented to the grain at an angle. In one place there seemed to be evidence of oligoclase feldspar slightly penetrating quartz, but again this might be simply an original pit in the quartz in which the feldspar had settled. If two grains were oriented crystallographically parallel with each other, neither would penetrate the other, but "mutual boundaries" or stylolitic boundaries should be evident. None was found.

As most of the grain relationship studies were made from thin sections, it might be argued that the plane of the section would cut very few grains at the point of their original contact. This is true, but for the amount of secondary en-

largement shown by the sections (assuming all the silica for enlargement came from solution of quartz at points of contact), there should be more evidence of penetration, because as grains interpenetrate, the area of contact would become larger and should provide greater opportunities for their intersection by the plane of the thin section.

Silica might be derived from the very fine grains of quartz. It is notable that below approximately the 0.02- or 0.01-millimeter-diameter group, primary quartz grains are almost absent, and the percentage is relatively low up to the 0.04-millimeter-diameter group. It would be expected that in a normal distribution some fines of quartz might be present. It is well known that the finer a material, the more surface in proportion to its mass it exposes to attack, and, therefore, it is easier for it to go into solution. The solution of these fines is a very good possible source of the secondary silica. Of course, it is these same fines which are taken into solution during transportation prior to deposition, and they might be largely removed by the transporting agent. However, the relatively pure rain and stream water would be a much poorer agent of solution than the sea water and connate brines, and sediments from present-day rivers apparently contain a normal distribution of these finer-grade sizes. One fact might contradict this hypothesis: one or two small fragments were found that had been chipped off the quartz where it had been subjected to pressure during the compaction of the sandstone. These did not appear appreciably to have gone into solution, since edges and corners were still sharp and they could be fitted into the place where they were chipped out.

In several grains there is evidence of replacement of quartz by other minerals. The alteration and replacement of quartz by sericite or penninite would release some silica, but the amount would be small, as such replacement is exceedingly rare. In a few cases, calcite appears to have replaced some quartz and this might release a little silica. This appears to take place in the zones where calcite is dominant. These replacements are almost invariably confined to the secondary quartz enlargements and rarely affect the original quartz cores. These solutions and replacements are not sufficient to be an original source of the silica.

Decomposition or alteration of silicates in the rock might yield a small supply of silica for secondary enlargement. The small fragments of silicates, like the small fragments of quartz, would be especially susceptible to solution and leaching of the silica. Some mafic minerals, such as hornblende and biotite, have been partly decomposed to clays and chlorite since deposition. During decomposition, some free silica might be released.[19] Clay minerals might be reorganized to yield some

[19] Is has been found that many minerals recovered from sandstones show evidence of solution. Recently, M. N. Bramlette, "The Stability of Minerals in Sandstone," *Jour. Sed. Petrology*, Vol. 11 (1941), pp. 32–36, studied heavy minerals of the Miocene sandstones of California and reached the conclusion that unless unstable minerals, such as mafic minerals, are protected from solution by carbonate, they will be entirely leached away. A review of the mineralogy of the Bethel sandstone indicates that most of the very unstable minerals are present only because they have been armored and protected by secondary silica. What unprotected mafic minerals are present are all deeply corroded and altered, and it is believed that most of this alteration took place since deposition, as the grains

silica. In fact, many of the original grain boundaries are marked by what appears to be greenish chlorite, and this was probably originally clay. Whether a release of silica took place during this reaction is not known, as the original composition of the clay is unknown.

Silica deposited with the sand from sea water and silica deposited from the enclosed connate water are ultimately from the same source. There is no direct evidence for this origin of the silica. A few well rounded chert fragments are present. These might have been small masses of silica gel deposited at the same time as the sand. However, they appear to be well rounded detrital grains, as they show no evidence of dehydration or crushing into irregular shapes between the enclosing sand grains, as would be expected if they were deposited as a gel. In one slide there appeared to be some interstitial silica deposited as chalcedony.

The last possible source of silica is circulating water from an external source. There is no proof of any silica brought in by this method, although this is a possible source of some of the interstitial chalcedony. Some could come from solution of silica from the overlying shale. The connate and circulating waters both might contain salts which would aid in taking silica into solution. However, shale is relatively impervious and not much circulation across the formations would be expected.

There is no good evidence as to the source of the secondary silica in the Bethel, but most of it was derived either (1) from the sea or connate water, or (2) from the decomposition and solution of fine silica-bearing minerals. Neither did the solution of sand grains under pressure nor their replacement by other minerals yield more than a very minor fraction of the cement.

Krynine believes that 90 per cent of the cement of sandstones is primary.[20] This may be true in the Bethel sandstone, as very rarely are the cores of grains found actually in contact; instead, nearly all are separated by secondary silica. The lack of original grain cores observed in contact with one another can not be entirely due to the plane of the thin section. Instead, these grain cores must have been separated at the time of their deposition or shortly afterward, as would happen were they coated by a layer of silica.

Waldschmidt,[21] on the other hand, attributes most of the secondary silica found in a number of sandstones of the Rocky Mountain region to solution of the sand grains under pressure and the reprecipitation of the silica in regions where the pressure is lower.

---

are too decomposed to have withstood the abrasion accompanying transportation; the only minerals present in any abundance are the more or less stable species. Therefore, in the case of the Bethel sandstone, it is quite possible that originally there were many more unstable minerals, and that their present paucity is largely the result of decomposition and solution since deposition, the silica and other components going into solution or being precipitated in the open spaces of the sandstone.

[20] P. D. Krynine, oral communication.

[21] W. A. Waldschmidt, "Cementing Materials in Sandstones and Their Influence on Migration of Oil," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 25 (1941), pp. 1839–79.

CARBONATE

As has been mentioned, the carbonate cement occurs as little nodules enclosing a few quartz grains or as a more extensive deposit. Most, if not all, of it came directly from carbonate deposited simultaneously with the sand and later reorganized, so that it filled in the pores and further cemented the sand.

The carbonate fossils, which in recrystallization lost all cell structure and became large calcite crystals with the major organic fossil features still outlined by impurities, became the center around which additional carbonate brought in by solutions recrystallized. The additional calcite probably came from adjacent parts of the same or similar fossils, or in some cases possibly from dissolved detrital limestone grains or micro-fossils.

A brachiopod valve filled with sand provided an obvious source of calcite. Pressure of the sand grains on both the inside and outside of the shell dissolved the carbonate, giving a sutured outline to the shell. This carbonate was reprecipitated between the sand grains as a calcite cement, and wherever it was in actual contact with the calcite of the shell it had the same crystallographic orientation as the crystals making up the shell. Where not in contact, it might have a different orientation.

Where no apparent center of deposition exists, the thin section may have just missed cutting a fossil but has cut the carbonate halo about it, or the center about which additional calcite has been deposited was an original detrital grain of carbonate or a precipitated carbonate crystal. There is no evidence of this original grain, but each knot of calcite cementation appears to have had some original nucleus around which to start the precipitation of the carbonate that was in solution in the interstitial liquid.

In certain zones where the Bethel sandstone is very calcareous, there may be no evidence of secondary quartz enlargement. The carbonate has recrystallized, but was probably deposited at the same time as the sand grains, either as a chemical or organic precipitate, since all the quartz grains are well separated from each other and there is no evidence of any reorganized carbonate from fossils.

Some of the carbonate appears to have attacked the quartz grains incipiently but not to any great extent. Where carbonate is present and surrounds the quartz grains, there does not appear to be any secondary enlargement. This does not seem to be the result of replacement of secondary silica, as there is no indication of any replacement of the quartz core. However, where a quartz grain is only partly surrounded by calcite, the quartz grain may show enlargement on all sides. In the areas where there is a small knot of calcite which entirely surrounds quartz grains so that they show no enlargement (whereas quartz grains adjacent to these knots do show enlargement), this calcite may either be pre-quartz-enlargement or the carbonate ions in the interstitial solution in a small area around a fossil or carbonate grain prevented the silica from being deposited on the quartz. Carbonate was later precipitated in this area. Further evidence that some carbonate is pre-silica is found in a few rare cases where the secondary quartz enlargement

actually conforms to a carbonate crystal face. In most samples, the calcite is post-secondary quartz in that it fills the space between the quartz enlargements and conforms to the secondary quartz outlines. Ordinarily the carbonate penetrates openings between the sand grains only as far as they are open. That crystallizing carbonate exerts an appreciable force is seen in several feldspar grains which have been split along their cleavages by calcite.

AGE RELATIONSHIPS OF BETHEL CEMENTS

From the foregoing discussion of the Bethel sandstone, during the cycle of lithification the sequence of cementation and pore filling is found to be: (1) precompaction enlargement of quartz grains by silica, (2) initial compaction and bonding by clay pastes, (3) early calcite cementation, (4) deposition of secondary quartz, (5) deposition of calcite shortly followed by dolomite, and (6) chalcedony interstitial filling. Pyrite is related to these cements only in that it is post-secondary quartz and probably post-carbonate.

Although there appears to be a definite succession of cements, the succession represented by stages 3, 4, and 5 are dependent probably entirely on the physical conditions at the time of cementation and may be reversed or interchanged from place to place in the same formation.

PRE-BETHEL CEMENTS

Most sandstones are cemented by either carbonate, silica, or hematite. The Bethel sand grains which have gone through earlier cycles of deposition show no evidence of ever having been cemented by a carbonate. However, even though it had been so cemented, it is doubtful whether any traces of the carbonate would remain, as carbonate is readily soluble. There is good evidence of at least one, and in some of the quartz and glauconite grains two, earlier cycles of deposition during which there was secondary enlargement and cementation with silica. Also, some well rounded quartz grains show evidence of secondary silica enlargement during an old metamorphic cycle.

Some sand grains show good evidence of having been deposited either with a red shale matrix or with a definite hematite cement or having occurred in a deeply weathered red soil. The evidence does not indicate which, but certain sand grains have traces of red hematite in pits on their surfaces. Abrasion has removed all but the most protected hematite. Even of greater significance is the fact that the red staining has penetrated deeply into the quartz grains along small fractures. This episode of redbed occurrence seems to have been just prior to the last period of erosion and deposition. It should be noted that care must be exercised not to confuse oxidation stains from chlorites and clays of the present cycle with the older hematite cement.

VARIATIONS IN CEMENTATION

In the area studied, as a whole, there is apparently little variation in the degree of cementation or in the character of the cement. In one place there is evi-

dence of increasing carbonate cement with depth, but this is merely a more calcareous lens of the Bethel sandstone, as other long cores show no corresponding increase in lime content with depth. In the present study, data from wells which are drilled off structure and in non-producing areas are insufficient to indicate whether there is correlation between the cementation and structure.

Cementation, size, and sorting.—Generally, the finer the size of grain the greater the degree of cementation. This is natural, because the smaller the pores, the more easily they are filled with cement which may have come in part from the solution and reorganization of this fine material. Also, this filling is aided by the slow circulation of fluids. In the carbonate-cemented areas, the pores are completely filled. The size of the zone that has the pores thus filled depends almost entirely on the quantity and availability of carbonate. The size of the grains and the localization of carbonate cementation show no relationship to each other.

There appears to be little connection between cementation and the other parameters of the sand with the possible exception of sorting, which is an index of the presence, or relative absence, of fine material interstitial in the coarser.

Relationships of Oil Recovery to Physical Properties of Sandstone

Porosity and permeability tests were available on only three Bethel sandstone cores[22] in the area studied. As a result, quantitative data are not plentiful, although much information can be secured from a detailed microscopic study of the pores and pore patterns of the cores. Only an abstract of some of the more important features are presented in this paper.

The diameters of the pores in the Bethel sandstone are ordinarily small, averaging about 0.01 mm., but they range from considerably lower to higher than this. Very rarely a pore may approach the size of the sand grains themselves, but these are merely local pockets.

It is shown in Table II that as a rule an increase in the grain size increases both the porosity and permeability. If this fails to take place, cementation or clay content is nearly everywhere found to be heavier than normal. Neither shape nor roundness of the sand grains appears to bear any particular relationship to the porosity and permeability of the sandstone. The sorting of the sand has an influence, although not very marked. In general, increasing porosity and permeability accompany an increase in sorting. Thus, unless heavy cementation or excessive clay is present, size seems to be the controlling factor, and this, coupled with the degree of sorting, largely determines the porosity and permeability of the sample.

Although the total clay fraction of the Bethel sandstone is small as compared with the quartz, it is located in such a position as to exert a pronounced influence

[22] The data on the porosity and permeability tests of Bethel sandstone cores are found in R. J. Piersol, L. E. Workman, and M. C. Watson, "Porosity, Total Liquid Saturation, and Permeability of Illinois Oil Sands," *Illinois State Geol. Survey Rept. Inv. 67* (1940), pp. 35–40. It should be noted in that publication the data on the Jarvis Brothers' Sinclair 2, SW. ¼, NW. ¼, NE. ¼ Sec. 29, T. 8 N., R. 3 E., Fayette County, depth 1,463–1,474 feet, are for the Paint Creek "Stray" sandstone rather than the Bethel sandstone.

on migrating fluids, as the clay minerals are concentrated between the sand grains and thus occupy a large proportion of the pore channels. These channels may be smooth if quartz lines their walls, or very ragged if clay lines them. The micas and clays are found to lie either parallel with the walls of the channels, or, especially for the secondary fine chlorites, at right angles to the walls. This latter orientation would further retard fluid migration. Furthermore, if all minerals are oriented the same way, and they possess anisotropic properties toward both water and oil, they may produce a strong effect upon both the primary and secondary recovery of oil.[23] It is unlikely that fluid velocities would ever be high enough in the small channels of the sandstone to tear the clay loose and either open the pore channels or cause it to plug constrictions in the pores, except in areas immediately adjacent to a well.

Although some of the clays in the Bethel sandstone may swell upon hydration, none of the clays identified along the walls of the channels or as granules among the sand grains is noted for such swelling.

The abundant bedding planes of all types and sizes in the Bethel sandstone, together with the lenses, clay pellets, shale plates, fossil fragments, and similar barriers that lie at an angle to the bedding planes, might cause by-passing during water-flooding and influence the migration of fluids. The result is that small pockets of oil may be trapped and sheltered from the water-drive by these obstructions.[24]

In water-flooding of the Bethel sandstone, little difficulty would be encountered from soluble sulphates as they are in very small proportions. The carbonates, in general, are in too small amounts and are concentrated in too small nodules to cause much difficulty due to channelling. However, these may react with iron or other ions in the injected water-flooding solutions and plug the pores with insoluble precipitates.

Origin of Bethel Sandstone

General aspects of Chester sedimentation[25]

The clastic strata in the Chester series as a whole are generally thickest and coarsest in the region of southern Illinois and western Kentucky adjacent to the Ohio River.

[23] *Cf.* P. D. Krynine, *op. cit.*, p. 71.

[24] A careful microscopic analysis should accompany any mechanical analysis of a sandstone core. A mechanical analysis of a sample containing shale or clay flakes and pellets shows a high shale content, in fact, one much higher than normally expected from the value yielded by a permeability test. In the consolidated sandstone, the shale lens or pellet acts as a unit similar to a sand grain and does not appreciably block the pore channels, but during analysis the shale would be disaggregated and appear to make up a high percentage of the sample. Unless known to occur otherwise, this amount of free clay in the sample would normally be expected to be largely concentrated in the pore channels and therefore should greatly decrease the porosity of the sample. On the other hand, this same shale lens or pellet may retain a considerable percentage of oil due to by-passing, trapping, and absorption.

[25] *Cf.* J. M. Weller and A. H. Sutton, *op. cit.*, pp. 819–53.

The Bethel sandstone is thickest along the Ohio River in Hardin County in southeast Illinois, but it thins in short distances in all directions. Southeastward, near Princeton, Kentucky, it is about 30 feet thick, whereas it pinches out entirely in the vicinity of Elkton, Kentucky; northward it thins irregularly to about 30 feet, after which it remains nearly constant until it is beveled off by the pre-Pennsylvanian unconformity. A little south and east of St. Louis, Missouri, it is represented (?) by the Yankeetown chert, which may be 20 feet or more thick. Southeastward from St. Louis it thins to Union County, Illinois, where it is not more than 10 feet thick, and in places in Johnson County, Illinois, it may be absent. Figure 1 indicates these general relationships.

North and northeast of the Illinois basin, no outcrops of the clastic Chester sands are found. Whether they ever existed in these regions is problematical. On the west, Ozarkia was apparently a land mass and was never covered by Chester beds. On the southeast, Butts[26] has found Bethel sandstone in northwest Alabama but it thins and is absent in the northeast part of the state. Arenaceous beds of Chester age are plentiful in Arkansas and these sands become increasingly coarse southward. The direction of cross-bedding clearly indicates a northward direction of currents and a southern source of sediments.[27] There are no known land barriers to cut off the Arkansas basin of deposition from the Illinois basin.

ROCK TYPES FURNISHING BETHEL DETRITUS

It is evident that there is a wide variety of sources for the detritus making up the Bethel sandstone. Although igneous rocks are the ultimate origin of all this material, the immediate source apparently is mainly from an area of older sediments as is shown by (1) the detrital minerals which are almost entirely confined to stable varieties, (2) the fine grain size, high degree of rounding, and high sphericity of most of the quartz and heavy minerals, and (3) the presence of several periods of enlargement and the coating of many of the other minerals by secondary silica.

Evidence that some of the grains originally came from igneous rocks is found in the (1) high-temperature quartz grains, (2) pegmatite grains, (3) pyroxenes, and (4) possibly some of the amphiboles, micas, and other minerals.

There is good evidence that many of the grains originally had various metamorphic origins. Cordierite, sillimanite, and staurolite may indicate a thermal metamorphic origin, although some of the minerals could have come from regionally metamorphosed rocks. The numerous grains of granulated and mylonitized quartz indicate a dynamometamorphic source. The chlorite-sericite-schist grains might have come from any low-grade metamorphic area of rocks. Furthermore, a study of mineral inclusions from cores of a number of wells and different depths in the wells reveals that on the average 75 per cent of the grains contain "regular"

[26] Charles Butts, "Geology of Alabama: The Paleozoic Rocks," *Alabama Geol. Survey Spec. Rept. 14* (1926), pp. 41–230.

[27] C. Croneis, "Geology of the Arkansas Paleozoic Area," *Arkansas Geol. Survey Bull. 3* (1930).

mineral inclusions. If the criteria as established by Mackie[28] and to some extent confirmed by Tyler[29] are admitted, then much of the sand was derived from metamorphic terrains. However, much more investigation is needed on the subject of the meaning of different types of inclusions, their mineralogy, and the source rocks of the different types and varieties, before accepting Mackie's inclusion rules as final.

The composition of the land masses which originally furnished the detritus was probably granitic as is indicated by the abundance of acidic feldspar. However, the mafic and basic feldspars would rapidly alter or pass into solution leaving a "residue" indicating such an acidic character even though originally the source was in basic or semi-basic igneous rocks. Some of the material comes from basic terranes as is seen in the abundance of titanium-bearing minerals and spinel. Spinel, although occurring largely as inclusions, is found dominantly in basic igneous and metamorphic rocks.

DETRITUS WHICH HAS SUFFERED ONLY ONE CYCLE OF EROSION

Some of the grains have suffered only one period of erosion and therefore have been derived directly from some crystalline rock. This is revealed by the freshness, angularity, and low sphericity of the sand. Although the mean sphericity and roundness of some of the quartz and feldspar are high, individual grains may show lack of wear. This angularity may be in part due to fracturing, but in some cases the grain never has been rounded. Some of the blue-green and colorless apatite, garnet, and the colorless zircon grains still show some crystal faces. These slightly abraded grains may have been protected during some of their erosion history by a coat of secondary silica or by occurring as inclusions in other grains; but some are so large that they probably were primary grains which have not suffered extreme transportation.

Other heavy minerals such as some of the colorless apatite, green varieties of tourmaline, the inclusion-rich colorless zircons, and the gray-colored zircons, may appear considerably more rounded than the foregoing varieties, but much less rounded than others. These may have undergone only one period of transportation, but if so, this period was a long one, as some of these minerals abrade very slowly. Tourmaline fractures readily and it is questionable how well evidence of an earlier period of rounding would be preserved. The same is true for the feldspar and other minerals which possess good cleavage.

Mafic minerals are not abundant in the Bethel sandstone and are almost invariably much decomposed. They may have originated from an earlier sediment or from relatively close crystalline rocks which were deeply weathered, as the minerals are so chloritized that they could not have stood the abrasion accom-

[28] W. Mackie, "The Sands and Sandstones of Eastern Moray," *Trans. Edinburgh Geol. Soc.*, Vol. 7 (1896), pp. 148–72.

[29] S. A. Tyler, "The St. Peter Sandstone in Wisconsin," *Jour. Sed. Petrology*, Vol. 6 (1936), pp. 55–84.

panying long and repeated transportation. However, much of the final decomposition occurred while in the Bethel sandstone.

The large amount of sericitic and chloritic material, both as individual grains and as rounded aggregates of replaced quartz, may in part come from low-grade metamorphic schists. That metamorphic-schist land areas were present is seen in some of the weak aggregates that probably could not undergo more than one period of transportation. The intensity of metamorphism of the schists may have reached the biotitic stage. All the fine biotite would readily be chloritized during transportation and while in the Bethel sandstone. The few fresh flakes of biotite that are found probably represent coarser biotite derived from granites or gneisses. These coarse flakes were not completely broken up during transportation and because of their large size they have not been completely altered. However, the rounded quartz grains with sillimanite and staurolite inclusions which do not show evidence of having undergone an earlier cycle of sedimentation, indicate terranes with rocks more highly metamorphosed. The same is true for some of the rounded quartzite aggregates which are here and there present. These quartzites appear to have been relatively pure, as in all cases the aggregate was made up of quartz with no micaceous or other material. However, it is true that any such impurity would form a zone of weakness along which the aggregate would break, and the impurity might then be lost.

Those quartz and feldspar grains that show no evidence of earlier enlargement and that are found as well rounded grains may have come from a distant granitic or gneissic source. Many of the metamorphic and pegmatitic quartz grains, as well as many of the inclusion-rich grains, are also enlargement-free. However, the fact that these grains show no enlargement does not preclude the possibility of an earlier sedimentary cycle; in fact, their high roundness and sphericity may indicate that they have undergone more than one cycle of erosion, and the absence of the enlargements may be because: (1) during the earlier period of deposition cementation may have been by carbonate which has been entirely leached away, (2) cementation may have been by clay, as many of the grains show abundant recrystallized clay under their Bethel enlargement, or (3) the last cycle of transportation may have abraded away all traces of earlier silica cement. If they are derived directly from a crystalline mass, then the mass was distant and the grains have suffered extreme abrasion during the one cycle.

SEDIMENTS DERIVED FROM PRE-EXISTING SEDIMENTS

As has been indicated, most of the Bethel detritus has come from re-worked older sediments. Also, as has been indicated, some of the well rounded sand grains not showing enlargement were likewise probably derived from older sediments, and evidence of this origin has been removed except for their high degree of roundness, sphericity, and fine-grain size.

The mineral suite is almost entirely composed of stable minerals which are very well rounded. To attain the high degree of rounding and sphericity that some of these grains exhibit would demand several cycles of erosion. The fresh

non-stable minerals which are present may have undergone more than one cycle of erosion, but if so they were armored in some manner. One good example of this was a cordierite grain which had been coated at two different times by secondary silica. The cordierite in the core was still perfectly fresh, although the grain must have been eroded at least three times. The same is true for some of the glauconite and other minerals. The scattered, much altered mafic minerals may have been derived from a pre-existing sediment rather than from a deeply weathered primary crystalline mass. However, most of the unstable varieties have been lost during earlier cycles of erosion and by solution during periods of deposition, and only the most stable residues remain.

Other than the fact that the grains are better rounded than would be anticipated if they had undergone only one cycle of erosion, a large percentage of the sand contains proof that its immediate origin lay in the different types of older sedimentary sandstones: (1) sand from older red terranes, and (2) sand from an older siliceously cemented sandstone composed of well rounded sand grains.

Many well rounded sand grains show traces of hematite on their surfaces and in fractures. The staining appears to belong to the last cycle of erosion prior to Bethel deposition, as there is only the one coating of silica. No grains were observed which revealed evidence of a sedimentation cycle prior to the red staining. In many cases the red-stained grains showed pitting. In no instance was a period of earlier enlargement observed on frosted grains. The red-stained grains which show frosting are believed to have undergone a period of eolian abrasion followed by deposition in the redbed environment; other red-stained grains may have had this origin or may have been stained by deep oxidation of the soil prior to their transportation. However, even the latter are from an older sediment rather than from a decomposed crystalline rock, as is indicated by their extremely high sphericity and roundness.

Many grains disclose abundant evidence of an earlier cycle of erosion and deposition under conditions in which silica cementation took place. These grains show no evidence of any redbed origin, although some may have come from that environment but have had all the hematite removed by abrasion and solution.

The shaly material was probably largely derived from older shale sediments, although some of the clay and other very fine detritus undoubtedly came from the fine material produced during transportation of the coarser detritus, and also from material resulting from surface weathering and decay in all areas furnishing sediments. Evidence that some of the shale is from an older sediment, and that the source of this sediment is not far distant, is found in the shale fragments here and there present. However, some of these shale plates may have come from dried mud flats. The little clay pellets represent either shale fragments which have been broken more than most of the shale fragments were, or small clay balls developed during transportation.

Rounded quartz pebbles in southwest Illinois indicate a near-by land mass furnishing coarse material, probably from a conglomerate.

Highly spherical chert grains are found which may have originated in a lime-

stone, although no evidence of detrital limestone is found. None of the chert shows enlargement or an earlier cycle of erosion. In some cores from southwest of the area there are thin, dense, limestone plates very similar to the shale plates mentioned. These, like the shale fragments, may represent limestone beds deposited contemporaneously with the Bethel formation but broken by wave action.

SUMMARY OF ROCK TYPES FURNISHING BETHEL SANDSTONE

Some of the Bethel detritus has undergone only one cycle of erosion. Based on the comparatively low roundness and sphericity of some of the sand grains, the presence of weak schist fragments, and the highly altered mafic minerals, it is evident that some of the detritus could not have undergone excessive transportation prior to deposition. Some of the heavy-mineral grains exhibit an intermediate degree of roundness, and these, together with the non-enlarged, well rounded quartz grains may have undergone only one long period of erosion and transportation. However, most of the detritus was derived from older sediments. That the source was near by, at least in part, is indicated by the quartz pebbles and shale flakes. Most of the detritus, even though coming from a pre-existing sediment, has suffered a long transportation history since an extremely high degree of roundness and sphericity is exhibited by some of the heavy minerals, and even the secondary silica coating on the grains is well rounded. This rounding could be attained only by long transportation.[30]

POSSIBLE LAND MASSES WHICH FURNISHED SEDIMENTS TO ILLINOIS BASIN

The land masses which could have furnished the Bethel sediments are: (1) Appalachia on the southeast and east, (2) the Canadian shield and Wisconsin highlands on the north, (3) Ozarkia on the west, and (4) Llanoria[31] on the south or southwest.

APPALACHIA

Whether there was a direct connection between Appalachia and the Eastern Interior basin is not evident. As has been indicated, Bethel sandstone is found in Alabama and thins eastward towards Appalachia. The rest of Appalachia probably contributed its sediments into the Appalachian geosyncline which was separated from the Eastern Interior basin by the Nashville dome, Cincinnati arch, and Kankakee arch.

The Bethel sandstone thins southeastward and eventually pinches out entirely but otherwise does not seem to change appreciably. The overlying and underlying Paint Creek and Renault formations change from clastic littoral de-

[30] G. A. Thiel, "The Relative Resistance to Abrasion of Mineral Grains of Sand Size," *Jour. Sed. Petrology*, Vol. 10 (1940), pp. 103–24.

[31] W. A. J. M. van der Gracht, "Permo-Carboniferous Orogeny in South-Central United States," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 15 (1931), p. 1050, has proposed that Llanoria did not exist as a crystalline mass but instead the crystalline rocks were originally far removed, and must have belonged to the continental complex generally known as the Paleozoic Gondwana block.

posits along the Mississippi River to shales farther southeast, and eventually consist of a considerable section of pure limestone beyond the limits of the Bethel and Aux Vases sandstones. This would indicate that no great amount of clastic material was being derived from the southeast, probably due to the shielding effect of the Nashville dome.

Eastward and to the northeast the Cincinnati arch and Kankakee arch likewise shielded the basin from sediments from Appalachia. Beds of Chester age were deposited on the east side of the Cincinnati arch but they thin onto the arch. In the Illinois basin the Bethel sandstone likewise thins from the deeper portion of the basin eastward and northeastward onto the two arches, and it may become quite shaly. The underlying and overlying formations, which in the southeastern part of the basin were almost entirely limestone, break up into a series of limestone beds separated by shaly beds or arenaceous beds northward from Kentucky. This clastic material is the result of sedimentation from land lying to the north.

CANADIAN SHIELD AND WISCONSIN HIGHLANDS

As has been indicated, there is some initial thinning of the Bethel sandstone northward from the center of the basin, but thereafter it does not thin appreciably until it is truncated by the pre-Pennsylvanian erosion. Furthermore, in the lower Chester formations additional arenaceous beds are introduced northward. Weller and Sutton[32] note a reduction in thickness of the limestone northward, as would be expected if a land mass were furnishing sediments from that direction. If some of the pre-Chester sandstones were exposed in the Wisconsin highlands, they may have supplied some detritus.[33]

Although the St. Peter sandstone shows frosted sand grains, some of which occur in redbeds, yet this formation probably did not directly furnish much of the sand. The median weight size for the St. Peter sandstone averages 0.22 mm. in diameter, but for the Bethel sandstone the corresponding measure, converted from numerical data, is approximately 0.12 mm. Furthermore, the weight percentage of the St. Peter sand less than 0.125 mm. is almost invariably considerably less than 20 per cent, and that fraction less than 0.062 mm. is less than 5 per cent.[34] Therefore, even winnowing the finer-grade sizes from the St. Peter and concentrating them in the Bethel would not have supplied all the detritus for the Bethel. The coarser grains would have had to undergo considerable erosion to reduce them to the Bethel sizes. This reduction in size would have removed all evidence of frosting and red staining. Furthermore, the fine grains of the St. Peter are ordinarily rather free of frosting while many of the fine grains

[32] Weller and Sutton, *op. cit.*, p. 844.

[33] The Hamilton of the Devonian is the first division of the Paleozoic represented in Wisconsin, and the whole area evidently has been above sea-level since that time. However, extensive pre-Devonian sediments are present. *Cf.* G. W. Pirtle, "Michigan Structural Basin and Its Relationship to Surrounding Areas," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 16 (1932), p. 49.

[34] G. A. Thiel, "Sedimentary and Petrographic Analysis of the St. Peter Sandstone," *Bull. Geol. Soc. America*, Vol. 46 (1935), pp. 559–614.

in the Bethel are frosted. Also, as Table IV shows, the heavy-mineral suite of the St. Peter sandstone would have to be greatly modified, especially in regard to zircon and tourmaline. In the St. Peter sandstone, zircon is the most important heavy mineral and is typically colorless or pink; tourmaline is next in abundance and is typically brown with some green and blue and other varieties.

TABLE IV

HEAVY MINERALS OF VARIOUS PALEOZOIC AND PRE-CAMBRIAN FORMATIONS

Formation and Location	*Tourmaline*	*Zircon*	*Garnet*	*Anatase*	*Apatite*	*Rutile*	*Staurolite*	*Leucoxene*	*Ilmenite*	*Hornblende*	*Epidote*
Bethel sandstone—Ill.	C	P	X	—	P	X	X	A	A	X	X
St. Peter sandstone—Wis.[a]	C	D	X	R	X	X	X	C	P	—	—
St. Peter sandstone—Kans.[a]	D	D	X	X	—	—	—	—	—	—	—
St. Peter sandstone—Minn.[a]	A	A	X	—	—	C	R	C	C	X	—
St. Peter sandstone—Ill.[a]	A	D	X	—	P	—	—	—	—	—	—
St. Peter sandstone—Ark.[a]	F	D	—	P	P	P	—	P	—	—	—
St. Peter sandstone—Ia.[a]	C	F	—	—	—	R	—	X	—	—	—
St. Peter sandstone—Mo.[a]	D	D	—	X	—	—	—	X	—	R	—
Madison sandstone—Wis.[a]	C	D	R	R	—	R	—	C	—	—	—
Madison sandstone—Wis.[b]	R	P	F	—	—	X	X	—	X	—	X
Jordan sandstone—Wis.[b]	P	C	D	—	—	X	—	X	X	—	X
St. Lawrence sandstone—Minn.[b]	C	F	X	X	—	—	—	—	—	—	R
Franconia sandstone—Wis.[c]	C	P	F	X	X	X	—	X	X	—	—
Mazomanie sandstone—Wis.[c]	C	R	F	—	—	X	—	—	X	—	—
Dresbach sandstone—Wis.[d]	C	A	R	X	—	—	—	R	P	—	—
Eau Claire sandstone—Wis.[a]	R	A	C	R	—	R	X	C	A	—	—
Mt. Simon sandstone—Wis.[a]	C	C	R	X	X	X	X	C	D	—	—
Roubidoux sandstone—Mo.[e]	A	D	—	—	—	—	—	P	—	—	—
Lamotte sandstone—Mo.[e]	C	D	—	—	—	—	—	P	—	—	—
Gunther sandstone—Mo.[e]	A	D	—	—	—	—	—	R	—	—	—
Keweenawan sandstone and arkose (Canadian shield)[a]											
Chequamegon sandstone	X	P	X	—	R	X	—	P	F	—	—
Devils Island sandstone	C	D	X	X	R	R	—	R	R	—	—
Orienta sandstone	R	P	—	—	R	—	—	P	F	—	—
Oronto formation	X	R	P	—	—	X	—	R	A	—	D
Barron quartzite	X	A	—	R	—	X	—	C	A	—	—
Hinckley sandstone	R	F	—	—	—	R	—	C	R	—	—

Notes:
F = 75–100 per cent
D = 50–75 per cent
A = 25–50 per cent
C = 10–25 per cent
P = 5–10 per cent
R = 1–5 per cent
X = less than 1 per cent

[a] After data compiled by S. A. Tyler, "The St. Peter Sandstone of Wisconsin," *Jour. Sed. Petrology*, Vol. 6 (1936), pp. 55–84.
[b] J. W. Ockerman, "A Petrographic Study of the Madison and Jordan Sandstones of Southern Wisconsin," *Jour. Geology*, Vol. 38 (1930), pp. 346–53.
[c] A. Pentland, "The Heavy Minerals of the Franconia and Mazomanie Sandstones, Wisconsin," *Jour. Sed. Petrology*, Vol. 1 (1931), pp. 23–36.
[d] W. L. Wilgus, "Heavy Minerals of the Dresbach Sandstone of Western Wisconsin," *ibid.*, Vol. 3 (1933), pp. 83–91.
[e] C. D. Cordry, "Heavy Minerals in the Roubidoux and Other Sandstones of the Ozark Region, Missouri," *Jour. Paleontology*, Vol. 3 (1929), pp. 59–85.

Apatite may rarely be present. Leucoxene is present in varying amounts. In the Bethel sandstone, leucoxene is ordinarily the dominant mineral and where coupled with ilmenite and magnetite, comprises more than three-quarters of the heavy-mineral content. Tourmaline is next in abundance and is dominantly an

olive-green variety, with the deep green to brown variety occurring but rarely. Blue-green tourmaline is ordinarily found in quartz inclusions. The zircons are not abundant and are dominantly yellow to yellowish brown varieties, with some colorless ones. Pink varieties are essentially absent. Apatite is not abundant, but is present in all slides.

Table IV lists the heavy minerals of other pre-St. Peter sandstones as well as those of the Bethel. In general, the Mt. Simon mineral suite is most similar to that of the Bethel. The typical tourmaline of all of these sandstones, however, is brown, with green and blue varieties distinctly minor. Table V gives the median

TABLE V

MEDIAN SIZES OF VARIOUS PALEOZOIC SANDSTONES

Formation and Location	*Median Weight Diameter in Millimeters*
Bethel sandstone—Ill.	0.12 approx.
St. Peter sandstone—Minn.[a]	0.22
St. Peter sandstone—Wis.[a]	0.22
St. Peter sandstone—Ill.[a]	0.46
St. Peter sandstone—Mo.[a]	0.16
St. Peter sandstone—Ark.[a]	0.24
New Richmond sandstone—Minn.[a]	0.25
Jordan sandstone—Minn.[a]	0.21
Franconia sandstone—Minn.[a]	0.11
St. Lawrence formation—Minn.[a]	0.05
Dresbach sandstone—Minn.[a]	0.08

[a] G. A. Thiel, "Sedimentary and Petrographic Analysis of the St. Peter Sandstone," *Bull. Geol. Soc. America*, Vol. 46 (1935), pp. 559–614.

diameters of a number of these sandstones. The Franconia contains too many garnets to have been the source; the Dresbach sandstone fits the mineral assemblage except that the zircons are too abundant; the St. Lawrence formation likewise contains too many zircons. The tourmalines, like those of the St. Peter sandstone, are dominantly brown with some green varieties.

North of the Paleozoic outcrop is the main Canadian shield which could have furnished some of the feldspar and metamorphic quartz and schist fragments. Heavy-mineral analyses of Keweenawan sandstones and arkoses are listed in Table IV. Much of the leucoxene and other opaque minerals could have come from this direction but no mineral suite typically fits the Bethel, although loss of zircons and garnets and dilution from other sources would not preclude the possibility of some of the detritus coming from the Orienta sandstone or other formations.

OZARKIA

Between the Wisconsin highlands and Ozarkia there is no evidence of any source of sediment. The land mass of Ozarkia, which occupies northern Arkansas and southern Missouri, probably is the source of much of the clay, limestone, and shale fragments, none of which could have stood excessive transportation. The

chert grains found here and there in the Bethel may have been derived from the pre-Chester cherty limestones, and the rounded quartz pebbles in the Bethel in southwestern Illinois undoubtedly came from a pre-Chester Ozarkian conglomerate. Both the white and the red-stained sand grains may have been derived in part from deeply weathered and oxidized old red soils, and these soils may have furnished the red clay for the red Bethel and Chester shales. Sand grains in these soils might be either pitted or polished by solution work in the ground. Ozarkia may have furnished some clastic material from pre-Chester sediments, but because of the small percentage of clastic material in the older rocks and their limited exposure, they could hardly have been a major source.The St. Peter sandstone in Missouri might have furnished some detritus, because, as Table IV shows, a slight loss in zircon content and an increase in titanium minerals, as from the Canadian shield, would develop a heavy-mineral distribution identical with that found in the Bethel except that the Bethel tourmalines are dominantly olive-green, whereas the Missouri St. Peter tourmalines are brown, with small amounts of green and blue varieties. The same difficulty exists in considering the other pre-Chester sands of Missouri as a major source of detritus for the Bethel sandstone.[35] Table V shows that in size distribution, the Bethel sandstone is closely comparable with the Missouri St. Peter. Even though the central granitic core of Ozarkia was exposed, the granite probably did not furnish much of the sand, because (1) by Bethel time the pre-Chester sediments could not have been removed from a very large area of the granitic core, and (2) the quartz grains could not have been transported far enough to produce such uniformly high rounding, sphericity, sorting, and fine-size distribution as is found in the Bethel sandstone. However, some of the less altered and angular heavy minerals and feldspar may have been derived from the granite core as perhaps were some of the quartz pebbles.

Ozarkia's main role consisted in being a shield which protected the west side of the basin from excessive sedimentation from Llanoria,which lay at the southwest. This is borne out by the fact that along the Mississippi River the Bethel sandstone is very thin or almost absent in places, while farther eastward where the sea was more open and where the basin was deeper the formation is much thicker.

LLANORIA

It is known that during Chester time Llanoria was a highland undergoing active erosion and furnishing large amounts of clastics which were deposited north of the land mass in the Ouachita geosyncline. As no known barrier separated the Illinois basin from the Arkansas area of deposition, Llanoria could have furnished a considerable quantity of the Illinois basin clastics.

In regard to the petrology of the Llanoria rocks, few data are available. How-

[35] C. D. Cordry, "Heavy Minerals in the Roubidoux and Other Sandstones of the Ozark Region, Missouri," *Jour. Paleontology*, Vol. 3 (1929), pp. 59–85.

ever, Miser[36] implies that it was a pre-Cambrian crystalline mass. This could be the source of some of the more rounded and spherical igneous and metamorphic grains. Associated non-metamorphosed Paleozoic (?) sediments might have yielded additional sand, clay, and chert. Their long transportation both in rivers and as wash along the shores would have amply abraded the grains to produce their fine size and high sphericity and roundness. This would be especially true of any material derived from pre-existing sediments and would explain the two degrees of roundness exhibited by some of the heavy minerals; some fairly well rounded ones have suffered only one long period of erosion while other well rounded ones have undergone a second cycle.

This conclusion as to the origin of the Bethel sandstone, which has also been reached by McCartney[37] and by Weller and Sutton,[38] has certain difficulties: (1) little is known as to the mineralogical composition of Llanoria, and (2) although only an approximate correlation of the sediments of Arkansas and the Illinois basin is possible, the Arkansas Chester deposits are only about half the thickness of the Illinois Chester, and the alternations of sandstones, shales, and limestones are absent.

The increased total thickness of the Illinois Chester can be explained by the fact that it may represent a longer period of sedimentation,[39] by the fact that the Illinois basin was slowly subsiding, forming a good catch-basin for the detritus, and by the fact that it received some sediments from other land masses. This last is especially true of the upper Chester and Pennsylvanian formations which seem to have derived a considerable quantity of detritus[40] from the east and southeast. Also, the fact that there is a rhythmic alternation from sandstones to shales to limestones is readily explainable on the basis that the Illinois Chester was farther from Llanoria and that the basin of sedimentation apparently was a broad, shallow sea-way. Any oscillation in the sea and changes in the position and elevation of Llanoria would cause considerable changes in sedimentation conditions, and these would be more marked at some distance and in such an embayment than near the land mass furnishing the sediments. Each of these rhythmic Chester cycles would indicate preliminary pulsations which eventually culminated in the Wichita-Ouachita-Appalachian Permo-Carboniferous orogeny.

SUMMARY OF SOURCE OF SEDIMENTS

The sediments forming the Bethel sandstone were derived from a number of sources as is shown in Figure 6, and their complete blending and reworking by

[36] H. D. Miser, "Llanoria, the Paleozoic Land Area in Louisiana and Eastern Texas," *Amer. Jour. Sci.*, Vol. 2 (1921), p. 68.

[37] G. C. McCartney, *op. cit.*, p. 90.

[38] Weller and Sutton, *op. cit.*, p. 847.

[39] The exact correlation between the Arkansas and Illinois Chester has not been definitely established.

[40] Weller and Sutton, *op. cit.*, p. 845.

the agents of transport have produced the present Bethel sandstone. The larger part of the sediments came from Llanoria and were derived mainly from pre-existing sediments, but some were derived from metamorphic or igneous rocks.

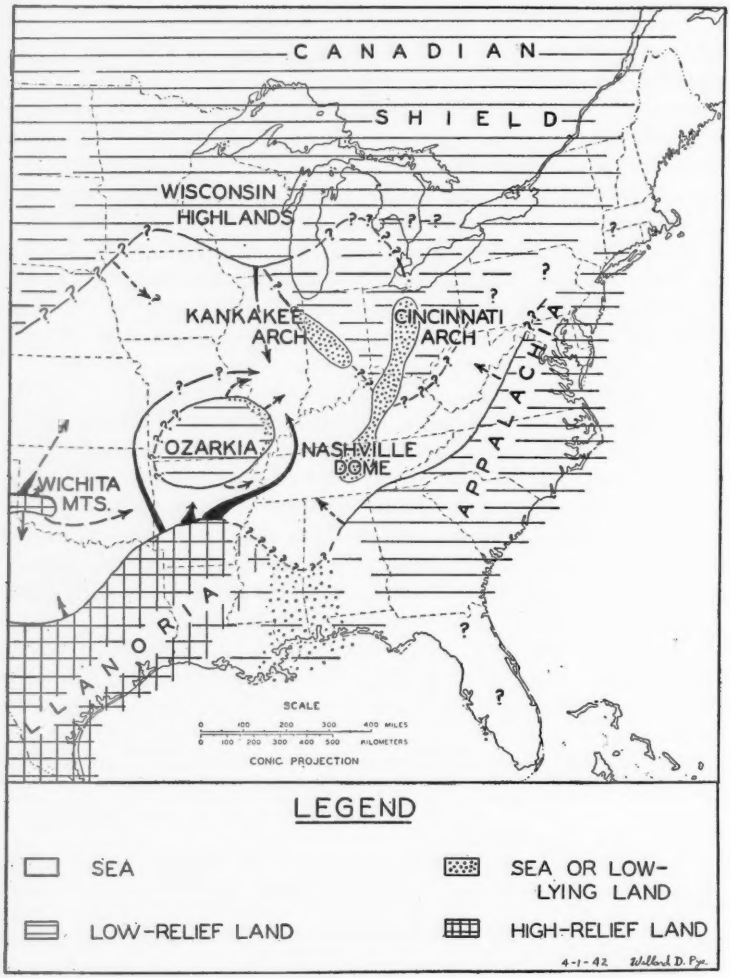


FIG. 6.—Paleogeography during Bethel time, and sources of sediments.

The Canadian shield was the second main source of sediments. The detritus was derived in part from Cambrian sandstones and in part from pre-Cambrian sedimentary, igneous, and metamorphic rocks. Ozarkia furnished much of the fine shale and some coarser detritus. The main source of the Ozarkian sediments was

from older Paleozoic sandstones, but some chert came from limestones; some sand grains came from deeply weathered red soils, and the old Ozarkia granitic core furnished some fresh sand and heavy minerals.

TRANSPORTATION AND DEPOSITION

Ozarkia was a low, peneplaned land mass. Rainfall and temperature conditions caused deep oxidation and weathering of the soils. Sluggish streams flowing across the deeply weathered rocks and soils brought into the Bethel seas only the finest sand, silts, and shales, some of which were red from deep oxidation. Some coarser material was concentrated along the strand lines. All mafic minerals were deeply decayed and only the most resistant grains, together with carbonaceous matter from the vegetation covering the land, reached the sea.

Similar conditions existed at the north on the Canadian shield, although the land may have been a little higher and the streams larger so as to bring in coarser detritus than came from Ozarkia.

On the other hand, Llanoria was a highland being actively eroded and was furnishing much detrital material to the Ouachita geosyncline. Long transportation by waves, currents, and wind action—all of which abraded, rounded, sorted, polished, and frosted the sand—eventually produced the present Bethel sandstone. These currents and waves introduced the sediments into the Illinois basin from around both sides of Ozarkia, which was essentially an island in the Bethel seas.[41] Only the finer sands were carried out toward the deeper water in the center of the basin, because (1) the Bethel thickens north and east away from Ozarkia, and (2), as Figure 5 shows, the lines of equal median grain size trend roughly north and south and become finer in the direction of the deeper part of the basin in that area of south-central Illinois which has been intensively studied by the writer.

The seas were shallow, because ripple marks and intra-formational conglomerates are abundant, especially in the direction of Ozarkia. The great abundance of bedding planes, cross-bedding, and clay films likewise indicates frequently shifting currents, as expected in near-shore deposits. Furthermore, although some of the areas of deposition had relatively clear water, lagoons in which local lenses of highly organic, uniformly bedded, black shales were deposited, were not uncommon. In other areas carbonate was abundantly deposited but in most places was combined with argillaceous or arenaceous materials. In some places these apparently formed thin limestone beds which were broken by wave action after their formation and consolidation. These intra-formational, impure limestone and shale conglomerates would be expected in near-shore deposits where oscillations of the sea-level would repeatedly dry out the formations and then subject them again to wave action.

Glauconite is abundant in the Bethel. Although its mode of formation is not

[41] Weller and Sutton, *op. cit.*, p. 817, in their discussion of the Meramec series, indicate that clastic material was introduced into the Eastern Interior basin from the northwest. This land mass could have contributed small amounts of sediments into the seas on the north side of the Ozarkia island. However, the sediments from the south side of Ozarkia show the same mineralogical and other characteristics as those from the north side.

clearly understood, at the present time it is forming under near-shore marine conditions. Ordinarily it is associated with organic remains. It has been thought to be the result of the decomposition of iron- and magnesian-rich pyroxenes, amphiboles, and micas, or similar minerals. Possibly one reason for the prevalence of glauconite in the Bethel sandstone is that the water in which deposition occurred doubtless had a considerable amount of iron in it, because some of the detritus came from redbed regions, and the mafic minerals from Ozarkia were already much decomposed. Glauconite is essentially a hydrous silicate of iron and potassium; the redbeds could furnish the iron, and the sea water the potassium.

Evidence that not all of the detritus was deposited under stagnant lagoon conditions is found in much of the chloritic material, glauconite, and some clays which show oxidation along their outer edges. It is true that some of the oxidation may have taken place following deposition, but had reducing conditions existed at the time of deposition, predepositional oxidation probably would have been removed.

An examination of Figure 5 shows that there is considerable irregularity in the size distribution, and that one major northeast-southwest coarse zone is separated by two areas of much finer-grade material. This coarse zone may represent an off-shore bar and the areas of finer material may represent lagoon areas in the Bethel sea. This is further borne out by the fact that, especially in the southern area of fine sediment deposition, the Bethel cores may contain considerable shale, commonly black in color.

As the structure map of Figure 2 shows, east of T. 1 E. the formations thicken and the basin markedly deepens. Perhaps the size distribution might be less irregular, therefore, due to more open-sea conditions. Furthermore, the general chain of oil pools from Centralia to Louden extends almost due north and then swings northeast as though marginal to the basin and as an off-shore bar.[42] However, as has been pointed out, it was impossible to secure sufficient data to determine whether the area east of T. 1 E. has as irregular a size distribution as that on the west. Therefore, too much emphasis should not be placed upon the apparent highly irregular and local lagoon and bar types of deposition of the sediments west of T. 1 E. and the apparent regular, off-shore type of sedimentation east of this line.

POSITION OF BETHEL IN MISSISSIPPIAN-PENNSYLVANIAN SEQUENCE OF EVENTS IN ILLINOIS BASIN

Although the formations in the Chester series are similar, a complete understanding of the complex sedimentation in the basin can not be obtained from the

[42] Although the Louden oil field lies just north of the area, it probably represents an off-shore bar. The best sand areas are found along the edges, and the quantity of shale increases toward the center of the pool. The structure is relatively flat on top and has steep dips on the sides. The sand is thinnest in the center. This type of structure, and the cleanness of the sand, would result from an off-shore bar where the wave and current action would continually carry away the fines along the margins of the bar as well as build up these edges with coarser material. Oral communication, The Carter Oil Company.

study of only one formation such as the Bethel sandstone, but should be based on a detailed study of all its members, as the seas were oscillating and the borderlands were apparently shifting continuously throughout Chester time, although the same general geographic, topographic, and climatic conditions persisted. The Bethel sandstone is, however, fairly typical of the lower Chester sandstones in regard to grain types, mineralogy, and the parameters of the sand grains.[43] In the upper Chester formations, however, the limestones of the central part of the basin give way almost entirely to shale in the southeast,[44] indicating that starting about middle Chester time the Nashville dome barrier was no longer effective and the initial movements of Appalachia took place, culminating in the formation of the Appalachian Mountains. Apparently, in early Chester time, the main source of sediments was Llanoria; as time went on, more and more sediments were derived from the southeast and east, until by Pottsville time most of the detritus came from these directions.[45]

Summary

More than 40 mineral species have been identified in the Bethel sandstone of south-central Illinois; however, heavy minerals are not abundant. Varieties of tourmaline, apatite, zircon, and quartz are found. Fully as many, if not more data can be secured concerning the origin and history of any deposit by a detailed study of quartz and its varieties, enlargements, and inclusions as can be gained from heavy-mineral studies, and without the laborious procedure of making heavy-mineral concentrates. A further advantage is that heavy minerals may be altered or completely leached out of the formation after deposition of the sediment. The result is a mineralogy that consists almost entirely of tourmalines, zircons and similar stable minerals and is entirely different from what it was when the sediments were deposited. The quartz grains, on the other hand, are stable and would only be affected by secondary enlargements.

The Bethel sandstone is very uniform in all of its physical properties, both vertically and laterally. The numerical mean grain size is between 0.10 and 0.08 mm. diameter and the sand is very well sorted, most of the samples having a standard deviation of less than 0.50 phi unit. The shape ranges from 0.8 to 0.9 unit and the roundness averages 0.6 unit. No significant variations in the roundness and sphericity exist in the area as a whole, but a coarse zone trending northeast from central Clinton County seems to separate two areas of finer material. However, the size variation is so small and sampling errors are so large that too much emphasis should not be placed upon these variations.

The chief cement is silica which appears to have been mainly primary with some secondary cement derived from connate water and from the decomposition

[43] Based on analyses of a few non-Bethel sandstones made in connection with this study; conversations with various oil company subsurface geologists; Weller and Sutton, *op. cit.*, pp. 819–53; and G. C. McCartney, *op. cit.*, pp. 82–90.

[44] Weller and Sutton, *op. cit.*, p. 844.

[45] R. T. Chamberlin, oral communication; and field work by the writer.

and solution of fine silica-bearing minerals. Very little of the silica comes from the sand grains going into solution under pressure. The order of cementation is (1) calcite, (2) silica, (3) calcite, (4) dolomite, (5) chalcedony. The first three stages overlap and may be interchanged. Their succession is largely dependent on the local physical conditions in the various parts of the formation.

In an analysis of the relationships of the physical properties of that part of the Bethel sandstone studied to the porosity, permeability, and oil recovery, it was found that the most important factor is cementation and this is followed in importance by size and sorting. Subsidiary, but also of importance, are (1) mineralogy, which determines the wetability toward oil and water, the solubility, the chemical activity, and the swelling with wetting; (2) grain orientation and shape; (3) bedding planes and other films of clay, and (4) by-passing around abnormally large grains, aggregates, fossils, or other structural conditions.

The Bethel sandstone has had a very complex history. The oldest grains are igneous in origin. Some of them have undergone at least one period of erosion and deposition followed by a period of metamorphism, and then together with other grains suffered at least two other periods of erosion, transportation, and enlargement, prior to deposition in the Bethel formation. Some grains have short-circuited various pre-Bethel erosional stages. Wind and water abrasion completed the rounding of the grains prior to their final deposition in shallow, off-shore waters. Burial, compaction, and cementation, followed by structural deformation and further cementation, produced the Bethel sandstone as it is now found.

Most of the sediments were derived from the highlands of Llanoria which were undergoing active erosion and were furnishing large quantities of clastic material to the Chester seas north of the land mass. The low humid island of Ozarkia acted mainly as a barrier in the path of the Llanorian sediments. Its main sedimentary contributions were very fine-grained clays and muds, some coarse clastics, and some vegetable matter. The low "Wisconsin highlands" and the Canadian shield ranked second to Llanoria as a source of clastic sediments, but the quantity of detritus was decidedly minor.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 1 (JANUARY, 1944), PP. 123-126, 1 FIG.

GEOLOGICAL NOTES

ALGAL REEFS IN CRETACEOUS AUSTIN CHALK OF TERLINGUA DISTRICT, BREWSTER COUNTY, TEXAS[1]

J. HARLAN JOHNSON[2]
Golden, Colorado

In the Terlingua district at the top of the Austin chalk there are 20 or 25 feet of strata which form a transition to the Taylor marl. The typical chalky and slaty limestones of the normal Austin become shaly, slightly sandy, and darker in color. Small lenses and streaks of coarse shell coquina occur, and at one locality there are small but well developed limestone reefs. The latter are located in Sec. 248, Block G. 4, about ¼ mile east of the Fletcher Shaft of the Esperado Mining Company.

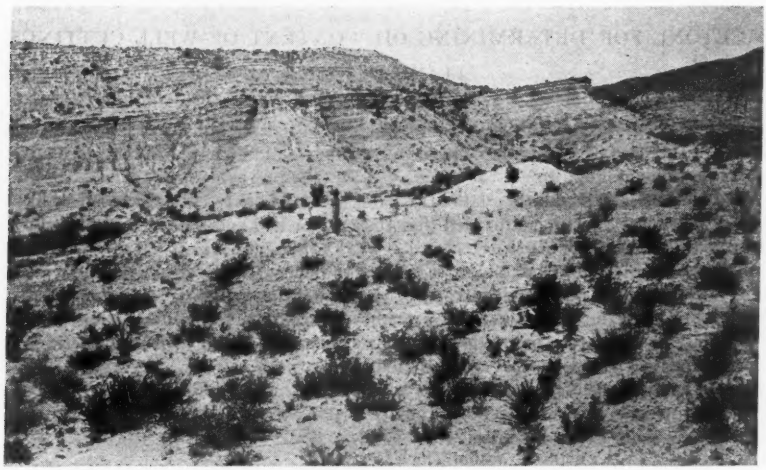


FIG. 1.—Small algal reefs form knolls by differential erosion. Terlingua district, Texas.

The reefs show a considerable range in size and variation in shape, from small lenticular masses of limestone to dome-shaped masses 20 or 25 feet across at the base and 8–10 feet high. In general they are small, averaging about 3 feet high and 10 feet across. The reef limestone is of several types, nodular, massive, or irregular cylindrical masses. These types may occur separately or together. In several places the lower part of the reef is composed of small nodular masses which become larger upward and fuse into a solid limestone mass above. The cylindrical forms developed within, around, or just above the reefs.

The reef limestones contain some fragments of shells and a few fossil molluscs, mainly pelecypods of the genus *Inoceramus*. The nodular masses, which are irregular egg- to biscuit-shaped, range from 2 to 8 centimeters long. The surface appears smooth although a glass will show it to have a felted or velvety texture. The cylindrical forms range from 2 to

[1] Manuscript received, November 6, 1943.

[2] Associate professor, Colorado School of Mines.

12 centimeters in diameter, averaging about 6. The larger ones are somewhat flattened. The massive reef limestones on weathered surfaces or on sawed specimens are seen to consist of numerous irregular algal colonies with the spaces between the colonies filled with fine chalky and silt particles. On the weathered surfaces the algal material takes a brownish gray color whereas the silt becomes yellow-brown. Some weathered masses show a coarse net-like surface texture. All the reef limestones weather to a dark brown tint which makes them stand out from the surrounding sediments which are much lighter in tone.

Thin sections of the limestone studied under the microscope show the rock to consist of a mat of fine algal filaments enclosing some foraminifera, tiny fragments of marcasite or pyrite and silt particles. The filaments average about 4 microns (0.004 mm.) in diameter. Some show branching. A few filaments of larger size (0.007 mm.) are present.

The algae appear to belong to sediment-binding types. As they grew on the shallow sea bottom, sediment, and organic débris became entangled in their filaments which held the material together. Gradually masses of impure calcareous material accumulated, eventually to form the nodules, lenses, and reefs.

ACETONE FOR DETERMINING OIL CONTENT OF WELL CUTTINGS[1]

LELAND W. JONES[2]
Colorado City, Texas

The following method for determining the oil content of well cuttings was developed because of the need of a fast simple procedure which could be used without access to laboratory equipment.

The method is particularly adapted to cable-tool carbonate cuttings but may likewise be used with rotary cuttings provided that they are picked and reduced approximately to the size of cable-tool cuttings.

Ether and chloroform have long been used to test cuttings for oil but the writer has found that acetone is far superior to any other extracting agent. Acetone immediately extracts any oil from the cuttings and the amount of discoloration provides an index of the oil content. Although acetone has undoubtedly been used by others as an oil-extracting agent, the writer has not found such a use mentioned in print.

The writer uses several small bottles which are ½ inch in diameter and 2 inches long. The procedure follows.

1. Pour in about ½ inch of acetone
2. Fill bottle with samples to within ½ inch from top
3. Fill with acetone
4. Shake
5. Let stand a minute to settle sediment

By comparing the resultant discoloration with a predetermined standardized set of solutions, an accurate comparison may be calibrated as follows.

1. No showing
2. Very light showing
3. Light showing
4. Showing
5. Good showing
6. Very good showing

The samples must be washed with water and dried. The length of time that the samples have been saved makes no difference. The test is accurate regardless of the fluid medium to which the samples have been exposed in the drilling process. Exposure to oil will not contaminate non-oil-producing samples and, likewise, water will not detract from the accuracy of the test. Samples need no special preparation.

[1] Manuscript received, November 12, 1943.

[2] Geologist, Anderson-Prichard Oil Corporation.

CARMI POOL, PRATT COUNTY, KANSAS[1]

JOHN E. GALLEY[2]
Wichita, Kansas

The Carmi pool, producing from Arbuckle dolomite (Cambro-Ordovician), is generally acknowledged to be the most important new pool in Kansas since the discovery of the Peace Creek pool in 1941. It is in northern Pratt County, in Secs. 28–33, T. 26 S., R. 12 W., and Secs. 25 and 36, T. 26 S., R. 13 W.

History.—The Shell Oil Company, Inc., surveyed the area by seismograph in 1941 and purchased leases on all available tracts on the prospect. Subsequently, E. Paul Hatfield promoted the drilling of H. M. Brown "B" No. 1, SW. ¼, SW. ¼, SE. ¼ Sec. 29, T. 26 S., R. 12 W., by the Hollow Drilling Company. Dry-hole money was contributed by the Champlin Refining Company, the Skelly Oil Company, and the Shell Oil Company, Inc.

Following is a list of subsurface markers which were penetrated.

	Feet
(Surface elevation)	1,912
Top of Topeka limestone	3,175
Top of Lansing-Kansas City groups	3,672
Top of Viola limestone	4,111
Top of Simpson formation	4,172
Top of Arbuckle dolomite	4,266

Casing was cemented at 4,269 feet on November 16, 1942, and at the depth of 4,280 feet the "pay" was treated with 2,000 gallons of acid. Later the hole was deepened to 4,297 feet, the final total depth, and, on January 21, 1943, a potential production of 6,391 barrels of oil per day was established by a draw-down test. The gravity of the oil is 40.4°, corrected.

While Brown "B" No. 1 was being tested, the Skelly Oil Company drilled its Knop "B" No. 1, SW. ¼, SW. ¼, SE. ¼, Sec. 25, T. 26 S., R. 13 W., a wildcat 2 miles west of the discovery well. This test likewise was completed as an Arbuckle producer, indicating that a pool of notable importance had been discovered. Subsequent development followed rapidly, and on November 24, 1943, the pool contained 65 wells and 4 drilling operations.

Geology.—The structure is a local anticline on the south flank of the Central Kansas uplift, and the accumulation of oil is presumably the result of structural entrapment. Dry holes north and south of the pool reveal the presence of relatively steep flanks which determine the limit of production on these sides. Vertical relief on the Arbuckle surface between the highest wells in the pool and the dry holes one mile north of the present pool boundary, is 170–190 feet. The west edge of the pool is marked by low wells having small potentials; the east edge has not been defined although its position is suggested by descending structural elevations.

The pay zones in Arbuckle dolomite are characterized by medium crystalline texture, the porosity being chiefly inter-crystalline; some vugs in zones of finer crystalline dolomite are oil-bearing. Sandy dolomite in the overlying Simpson formation is productive 1–2 miles southwest, in the adjacent Iuka pool, which is on the flank of the Carmi structure, and in one well at the south edge of the Carmi pool, but this bed has not been found to extend over the higher parts of the anticline.

Production.—Usual engineering procedures involve drilling with rotary tools to the top of Arbuckle dolomite, where casing is cemented, and completing the wells with cable tools or with rotary tools using reverse circulation. Commonly the pay formation is treated with 1,000–3,000 gallons of acid before completion of the well. With the exception of small

[1] Manuscript received, November 26, 1943. Published by permission of the Shell Oil Company, Inc.

[2] Shell Oil Company, Inc.

wells at the edges of the pool, which are completed by pumping, production potentials are established by the flowing draw-down method.

Of the 65 wells producing on November 24, 1943, a total of 49 had potentials greater than the 3,000-barrel daily production which has been established by the Kansas Corporation Commission as the maximum potential from which an "allowable" production may be computed. The remaining 16 wells established potentials of less than 3,000 barrels per day on initial tests. One of these, the only well in the pool not producing from Arbuckle dolomite, has a potential of 45 barrels of oil per day from sandy dolomite in the Simpson formation. At present only wells along the north edge of the pool are producing any water with the oil.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 1 (JANUARY, 1944), PP. 127-138, 2 FIGS.

REVIEWS AND NEW PUBLICATIONS

* Subjects indicated by asterisk are in the Association library, and are available, for loan, to members and associates.

OIL AND GAS FIELD DEVELOPMENT IN UNITED STATES. YEAR BOOK 1943 (REVIEW OF 1942), BY NATIONAL OIL SCOUTS AND LANDMEN'S ASSOCIATION

REVIEW BY W. A. VER WIEBE[1]
Wichita, Kansas

"Oil and Gas Field Development in United States." *Year Book 1943* (Review for 1942). *National Oil Scouts and Landmen's Association*, Vol. XIII (1943). 789 pp. Published by the National Oil Scouts and Landmen's Association, Austin, Texas. Price, $7.50, net.

The annual volume of the oil scouts and landmen is growing by leaps and bounds. This year several extra features help to increase the size of the book. Special articles by Harold Ickes and six other nationally known authorities serve as an introduction to the statistical part of the volume. The article by Warren Baker presents an excellent outline and over-all picture of the oil industry during the year 1942. Frederic Lahee has an article on the results of wildcat drilling similar to the one presented annually in the *Bulletin* of the A.A.P.G. An article by H. J. Struth contains a plea for more reserves. This article is comprehensive and very enlightening. It contains many good tables for reference on all items pertaining to the economics of the oil industry. A splendid article on the accomplishments of geophysical parties during 1942 by E. A. Eckhardt concludes the series of preliminary features.

In the statistical part of the volume there are more or less detailed reports on oil and gas operations in 26 different states, including Georgia, Florida, Utah, and Tennessee. The only states which seem to have been passed over are North Dakota and South Dakota. As might be expected from the population density of scouts and landmen, not all states share equally in the amount of detail presented. The states in the Mid-Continent area receive the greatest amount of space and are treated in very complete detail. Texas is accorded no less than 220 pages in the total of 789 pages. The state is divided into seven districts and each of the districts is described with a completeness which leaves very little to be desired (a possible exception is the Panhandle district). The new discoveries of 1942, the record of wildcats drilled, the operations of geophysical parties, acreage blocks leased, and other similar items are discussed fully. In addition, there is a separate map for each district showing the pools and a very extensive table telling the significant data for each pool. In this volume of the *Year Book* a systematic pattern has been set for the table of oil- and gas-field data. It is divided into three parts according to (1) geology, (2) well data, and (3) production data. Under the heading of geology the name, age, thickness, and depth of each pay formation is listed. In addition, the structure of the pool, method of discovery, and area are given. Under the heading of well data, the depth and age of the deepest test are given, together with all possible facts about oil wells, gas wells, and dry holes. Under the heading of production data, such items as gravity, allowable, daily average, total for 1942, total cumulative, recovery per acre, and reserves of the pool are included.

The remaining states in the Mid-Continent region are treated with approximately the same completeness as is the state of Texas. Louisiana is divided into three districts and New Mexico into two. In southeastern Louisiana a special feature is the discussion of sul-

[1] Geology department, University of Wichita. Manuscript received, November 27, 1943.

phur production, and in southwestern Louisiana a similar feature is introduced on the production of salt. In the treatment of the pools of northwestern New Mexico mention is made of the interesting discovery of helium gas in the Devonian Elbert formation on the Rattlesnake dome. For Oklahoma and Kansas the information is very complete. For Arkansas some additional items such as pipe-line runs and storage data are included. In the discussion of Mississippi there is a special map of the Tinsley field. For Alabama a good map is presented on which all dry holes drilled to date are shown. Southeastern Nebraska is treated under the heading of Forest City Basin. An excellent paleogeological map is presented to show the areal geology of pre-Mississippian time in Nebraska, and adjacent parts of Missouri, Iowa, and northeastern Kansas.

The Pacific Coast producing areas in California are treated with the same preciseness and completeness as in the case of the Mid-Continent states. The Rocky Mountain states of Montana, Wyoming, Utah, Colorado, and northwestern Nebraska are discussed in one group. New discoveries, geophysical operations, leasing activities, and acreage held by major companies are the chief items of the discussion. The table containing pool information is very much abbreviated. There are special maps of Lance Creek, Wertz dome, and Kirby Creek.

For the eastern states the information is much more limited, although there is much variation. For Michigan each pool is described in great fullness. There is a table of data on individual pools and also separate tables for acreage held, geophysical operations, and proration items. Illinois is treated in very complete fashion, but Indiana does not fare so well. For Indiana, however, there is a good map to show the location of the oil and gas pools of the state. For Ohio there is a short general discussion, but no table of pools. The same remark may be made for Pennsylvania, West Virginia, New York, Kentucky, and Tennessee. The petroleum economist will be disappointed in the material offered for these states. He may be particularly disappointed because the two areas in Kentucky are not treated separately. For Florida a very good map is presented on which all the dry holes are plotted which have been drilled to date. The same is true for Georgia.

Among the most valuable features of the present volume are the special articles and tables gathered together under the heading of Appendix. Here our members fill find very significant information on such diverse topics as world production, world consumption (of oil), crude production by states and by countries, producing record of major pools, completion data by states, data on cable and rotary drilling, summary of data on stripper wells, total discoveries in the United States during 1942, income of oil companies, crude-oil prices, pipe-line construction, and even a table for comparing the gravity, volume, and weight of crude oil.

The reviewer feels that the appendix alone is worth the price of the volume to any person interested in the oil industry. It is invaluable as a quick reference summary. For those who need to secure data on the economics of oil fields, especially in the Mid-Continent area, the book is indispensable.

ROCK COLORS

REVIEW BY RONALD K. DEFORD[1]
Midland, Texas

"Preliminary Color Standards and Color Names for Soils," by T. D. Rice, senior soil scientist, Division of Soil Survey, Bureau of Plant Industry; Dorothy Nickerson, color technologist, Agricultural Marketing Service; A. M. O'Neal, senior soil scientist, Division of Physical Surveys, Soil Conservation Service; and James Thorp, soil scientist, Division of Soil Survey, Bureau of Plant Industry. Paper. 6×9 inches, 12 pp., 6 figs., 8 color charts in pocket. *U. S. Dept. Agriculture, Misc. Pub. 425* (September, 1941). For sale by Supt. Documents, Washington, D. C. Price, $3.00.

[1] Argo Oil Corporation. Manuscript received, November 15, 1943.

Munsell Book of Color, Abridged Edition,[2] Vol. I (1929). Black fabrikoid; loose-leaf; boxed. Pocket size: $4\frac{3}{4}\times7\frac{1}{4}$ inches; leaves, $3\frac{3}{4}\times6\frac{3}{4}$ inches. 11 text pp. +1 folded text p. 22 color charts: a Munsell hue chart showing 10 hues of maximum chroma; a 9-step neutral-value scale; and 20 constant-hue charts (5R, 10R, 5YR, 10YR, 5Y, 10Y, 5GY, 10GY, 5G, 10G, 5BG, 10BG, 5B, 10B, 5PB, 10PB, 5P, 10P, 5RP, 10RP) showing color steps for lightness values from 2 to 8 inclusive and for chromas 2, 4, 6, 8, 10 (plus a few 12's and one 14). 3 neutral masks, not bound. $25. Munsell Color Company, 10 East Franklin Street, Baltimore 2, Maryland. 1929; revised text, additional colors, 1942.

"Method of Designating Colors," by Deane B. Judd, physicist, National Bureau of Standards, and Kenneth L. Kelly, research associate for the American Pharmaceutical Association at the National Bureau of Standards. Paper. $6\times8\frac{1}{2}$ inches. *U. S. Dept. Commerce, Natl. Bur. Standards Research Paper 1239.* Part of *Natl. Bur. Standards Journal of Research*, Vol. 23 (September, 1939), pp. 355–85; 5 figs., 36 color-name charts (diagrammatic, not colored). For sale by Supt. Documents, Washington, D. C. Price, $0.10.

Dictionary of Color, by A. Maerz, director, American Color Research Laboratory, and M. Rea Paul, consulting colorist, Research Laboratories, National Lead Company. Cloth, 9×12 inches, vii+207 pp., 56 color pls. $12. McGraw-Hill Book Company, New York (1930).

Color Standards and Color Nomenclature, by Robert Ridgway. A. Hoen and Company, Biddle and Chester Streets, Baltimore, Maryland (1912). Scarce. Quoted at $25 in 1942.

Color Chart for the Description of Sedimentary Rocks, by Marcus I. Goldman, chairman, and H. E. Merwin, Subcommittee on Color Chart of the Committee on Sedimentation of the Division of Geology and Geography, National Research Council, Washington, D. C. (1928). Out of print.

Soils and rocks.—Obviously the study of soils is closely related to the study of rocks; yet it is common practice in field geology to ignore soils. Perhaps the time is beginning to arrive when field geologists need to know a little about the different kinds of soils.[3] Different soils have strikingly different properties, and in most places the soils are economically more important than the rocks. Parry Reiche, W. Armstrong Price, Ed. W. Owen, and others have remarked that the soil scientists are in some respects quite in advance of us geologists and that we have much to learn from them. One of these respects seems to be the description of color.

Color names used by geologists.—The description by geologists of the colors of rock outcrops and rock cuttings from test wells is, I dare say, completely anarchistic: every man for himself. Field geologists report "brick red," "vermilion," "maroon," "magenta," "lavender," "violet," "red-brown," "brown-red," "orange-red," "pinkish orange-red," "yellowish purple," and so forth. On a field trip I called attention to a "yellow sandstone." "Do you mean that brown sandstone?," asked P. B. King. V. C. Perini, Jr., once said that a certain rock was characteristically chocolate-colored. Further discussion brought out that he "didn't mean the color of hot chocolate, but the color of the syrup on a chocolate sundae," or maybe it was the other way round. Subsurface geologists report "tans" and "buffs"; a dozen different dolomite members in West Texas are all described as "the brown lime," although some of them are gray. W. B. Lang[4] used such terms as "a rich dark ma-

[2] Also available is Abridged Edition, Vol. II (1941), with 20 constant-hue charts (2.5R, 7.5R, 2.5YR, 7.5YR, etc., through 7.5RP) designed to furnish closer hue steps when used in conjunction with Vol. I. $23. Also, Standard Edition (1929). Cloth. Folio: $10\frac{1}{2}\times13$ inches. 42 text pp., 32 pp. of color charts comprising 400 standard colors. $75.

[3] "Soils and Men," *U. S. Dept. Agriculture Yearbook 1938.* For sale by Supt. Documents, Washington, D. C. Price, $1.75 (vellum).

[4] Walter B. Lang, "Basal Beds of Salado Formation in Fletcher Potash Core Test, Near Carlsbad, New Mexico," *Bull. Amer. Assoc. Petrol. Geol.*, Vol. 26, No. 1 (January, 1942), pp. 63–79.

hogany color (deep Corinthian to dark Indian red)," and "a cocoa color (ferruginous to cinnamon-rufus)," and "(clear Paynes gray)," and "pale brownish gray (wood brown)," and "maltese to pearl gray (light mineral gray)," and "wine-red," and "salmon pink." The terms in parentheses have the advantage of being scientific; they are based on comparison with Ridgway's color charts. Ridgway's book, however, is practically unavailable to the great majority of geologists.

Although geologists now lag behind other scientists and technologists in the scientific description of color—at least those who deal mainly with sedimentary rocks lag behind—the scientific standardization of color names was founded 125–150 years ago by two geologists.[5] The famous Werner, Father of Mineralogy, worked out an arrangement of colors and color names, illustrated by a set of mineral specimens. Under the guidance of Professor Robert Jameson, another mineralogist, Werner's system was published in book form, the first edition in 1814, the second in 1821.

Subsequently color standardization advanced along somewhat divergent paths. Ridgway's work is a milestone along one of these paths. Maerz and Paul's dictionary represents a reconvergence and modern summary of the several lines of investigation of color *names*. The Munsell color system, on the other hand, attempts to analyze color gradations into equal steps of sense perception and to represent these steps by numerical scales so as to designate colors accurately.

In 1927 Grawe[6] proposed that geologists use photometers to determine rock colors quantitatively.

In 1928 Goldman and Merwin abridged Ridgway's 1,115 colors to a set of 114 colors on a two-plate chart designed for the use of geologists in the field. They recommended the supplementary use of Ridgway's book whenever possible. Colors on the Goldman-Merwin chart are not designated by name but by a system of symbols composed of numbers, letters, and numerical superscripts, which seems forbidding to the color novice. The chart did not attain general use and is now out of print.

The chief purpose of this review is to call attention to the booklet on color standards by the soil scientists, Rice, O'Neal, and Thorp, and the color scientist, Nickerson, published in 1941 as the culmination of several years investigation by committees and individuals. Its charts are useful for determining not only colors of soils but also colors of sedimentary rocks. It appears to lay the foundation of a simple, practical, and rapid system of color nomenclature for field and subsurface geologists; but for them it needs to be enlarged. This review is written from the viewpoint of a geologist, untrained in color, who studies rock outcrops and looks at specimens and cuttings under a low-power binocular microscope.

Color names used by soil scientists.—A committee of soil scientists assembled 250 samples representative of the range of soil colors and then subdivided them into five sets of 50, each set so chosen as to cover the entire range of samples. A total of 112 soil scientists examined the samples and described the colors; that is, about 21 observers examined each set of 50. There was little agreement on the exact name for each sample. A few observers tried naming the same set of colors twice and were unable completely to duplicate names, although there were no great discrepancies.

> The next step was to find a system of color names that could be sufficiently standardized to be acceptable to color scientists, sufficiently useful to be satisfactory to soil scientists, and sufficiently commonplace to be understood, at least in a general way, by the farmer.[7]

[5] Maerz and Paul, *op. cit.*, p. 137.

[6] Oliver R. Grawe, "Quantitative Determination of Rock Color," *Science*, Vol. 66, No. 1698 (July 15, 1927), pp. 61–62.

[7] Rice *et al.*, *op. cit.*, p. 6.

A practical color system.[8]—A particular color is the product of three factors: lightness (or brilliance, or value), chroma (or saturation, or purity), and hue. Each factor is analyzed qualitatively as follows.

1. Scale of lightness: very light, light, medium, dark, very dark. If the other two factors are both eliminated so as to obtain a "pure" lightness factor, one obtains a neutral scale that ranges from white through gray to black. A numerical scale with white as 10 and black as zero can be set up.
2. Scale of chroma: weak, medium, strong, vivid. Chroma is the degree of departure of color from neutral gray of the same lightness. The two factors chroma and hue can not be completely separated, but any single hue can range from weak to strong on the chroma scale as it can range from dark to light on the lightness scale. A numerical chroma scale with the zero among the grays at the "weak" end and 10 toward the "vivid" end can be set up.
3. Scale of hue: this is a closed series of hues ranging through red, yellow, green, blue, purple, and back[9] to red, including all intermediate hues in their proper positions.

The three factors can be represented graphically by means of a color solid. The numerical scale of lightness is taken as the vertical axis. Its middle point is taken as the zero of the scale of chroma, which is taken as a horizontal axis. The horizontal axis is then revolved through a complete circle to form the scale of hue.

The complete circular arc is subdivided into 100 gradational units of hue, ten being assigned to each of the following hues: red, yellow-red, yellow, green-yellow, green, blue-green, blue, purple-blue, purple, red-purple.

The solid figure so formed is not a cylinder. If red pigment, for example, is painted on a white surface the reflectance of that surface is diminished and the resulting color has a lightness of less than 10. If, however, the red pigment is added to a gray surface of the same lightness, the lightness factor remains constant but the chroma is increased. Perhaps the color solid can be described as a triaxial ellipsoid that has been squeezed between a dark yellow thumb and a light purple-blue finger, the vertical axis of lightness remaining unchanged during the squeezing.[10] For such practical purposes as are here under discussion it can be thought of as a sphere.

The soil scientists referred to this color solid for their fundamental description of colors. They found, however, that common usage is so strong in regard to certain designations that they were constrained to include in their scheme a few hue names that cover only a limited range of lightness and chroma. These are the following.

The *pinks*, which are very light reds
The *oranges*, which are light yellow reds medium to strong in chroma
The *orange pinks*, which are light yellow reds weak in chroma
The *browns*, which are a dark group of yellow reds
The *olives*, which are actually dark yellows

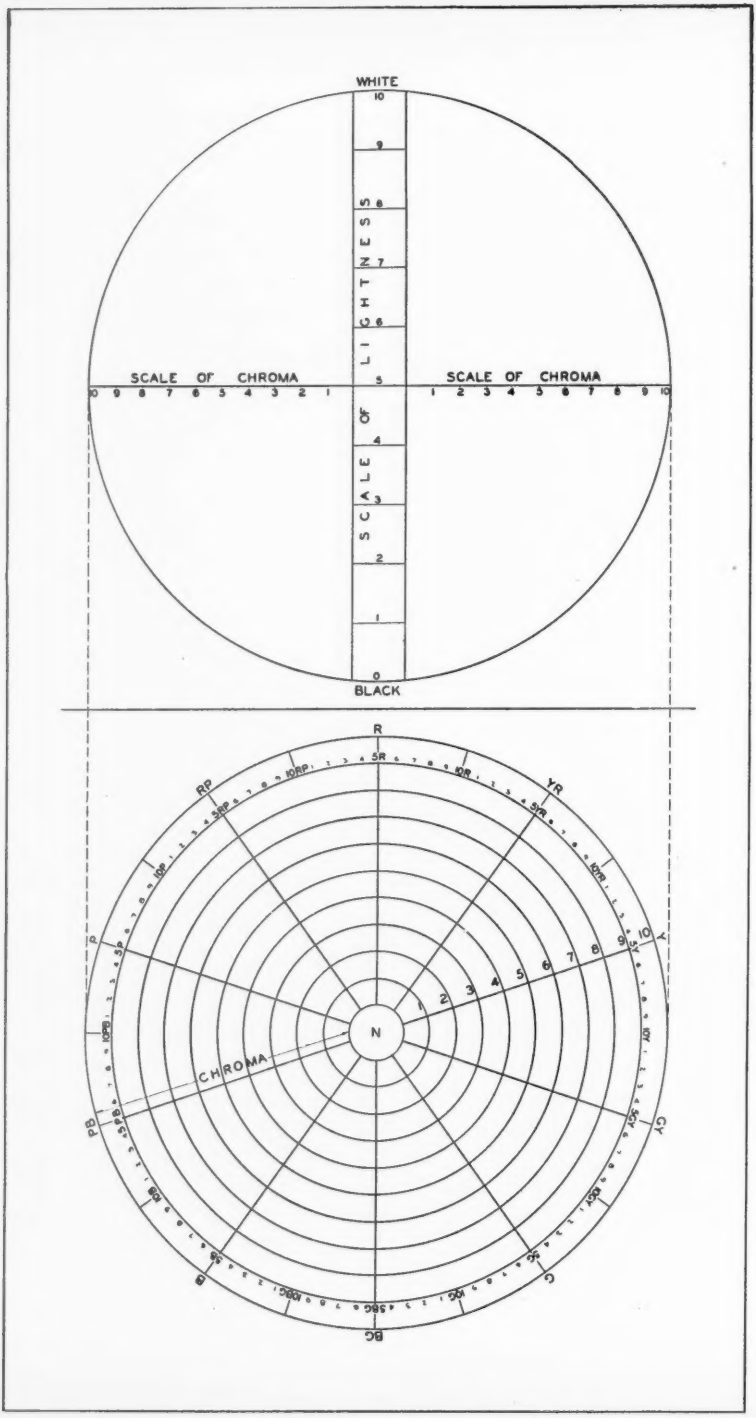
Lightness and chroma are described by means of adjectives which modify nouns describing the hue. The adverb *very* may further modify the adjectives where necessary. In order to avoid unwieldy adjective combinations the following terms are used.

Term	*Meaning: Lightness and Chroma*
Pale	Light and weak
Brilliant	Light and strong
Moderate	Medium and medium
Dusky	Dark and weak
Deep	Dark and strong

[8] The soil scientists followed the lead of Judd and Kelly, *op. cit.*, whose paper is a solution of "the problem of devising a system of color designations for drugs and chemicals . . . sufficiently standardized as to be acceptable and usable by science, art, and industry, and sufficiently commonplace to be understood, at least in a general way, by the whole public."

[9] A disconcerting misprint on page 7 of Rice *et al.*, *op. cit.*, reads "black to red" instead of "back to red."

[10] Dorothy Nickerson and Sidney M. Newhall, "A Psychological Color Solid," *Jour. Optical Soc. America*, Vol. 33, No. 7 (July, 1943), p. 421, Fig. 3.


WHITE
10
9
8
LIGHTNESS
7
6
5
SCALE OF CHROMA
10 9 8 7 6 5 4 3 2 1
SCALE OF CHROMA
1 2 3 4 5 6 7 8 9 10
SCALE OF
4
3
2
1
0
BLACK
R
5R
10R
YR
5YR
10YR
Y
5Y
10Y
GY
5GY
10GY
G
5G
10G
BG
5BG
10BG
B
5B
10B
PB
5PB
10PB
P
5P
10P
RP
5RP
10RP
N
1
2
3
4
5
6
7
8
9
10
CHROMA

Two color scientists compared each soil sample with Munsell color charts in order to estimate its color in Munsell notation; that is, the color of each of the 250 representative samples was determined numerically with reference to the color solid. Soil hues (Fig. 1) were found to range from 7R to 5Y; lightness from 2 to 8; and chroma from 0.5 to 8.

The results indicated that about 56 names would be necessary. Samples of the average color representing each of these 56 names were placed on 8 color charts[11] titled as follows.

Chart Titles

Reds and grays	Yellowish browns and grays
Reddish browns and grays	Olive browns and grays
Browns and grays	Olives and grays
Oranges and grays	Yellows and grays

The following are the 56 different colors illustrated on the charts.

White			
Light gray			
Medium gray	Reddish gray	Weak red	Moderate red
Dark gray	Dark reddish gray	Dusky red	Dark red
Black			
Light brownish gray	Pale reddish brown		
Brownish gray	Weak reddish brown	Moderate reddish brown	
Brownish black	Dusky reddish brown	Dark reddish brown	
Very pale brown			
Pale brown	Light brown		
Weak brown	Moderate brown	Strong brown	
Dusky brown	Dark brown		
Very pale orange	Light orange		
Pale orange	Moderate orange		
Weak orange	Dark orange		
Light yellowish brown			
Moderate yellowish brown	Strong yellowish brown		
Dark yellowish brown			
Light olive brown			
Moderate olive brown			
Dark olive brown			
Light olive gray	Pale olive	Light olive	
Medium olive gray	Weak olive	Moderate olive	
Olive black	Dusky olive	Dark olive	
Yellowish white	Pale yellow	Light yellow	
Yellowish gray	Weak yelow	Moderate yellow	
	Dusky yellow		

Circular holes in the charts adjacent to each color allow a soil or rock sample to be placed behind the cut-out portion next to the color it most nearly matches. This is convenient. The holes also permit the juxtaposition of closely related colors like light brown and weak orange for direct comparison with a rock fragment. The eight charts are fastened together with a staple at one corner so that they can be fanned out separately for use in the

[11] Text, p. 9, says 57 names and 7 charts, but the pocket contains 8 charts bearing 56 different names.

FIG. 1.—Plan (lower figure) and elevation (upper figure) of color solid showing three-dimensional relationship of hue, lightness, and chroma. Letters and numbers represent Munsell notation. Each unit of lightness and each unit of chroma can be subdivided into tenths. *N* means neutral. In this figure the color solid is idealized as a sphere; in practice, however, vivid chromas may lie beyond 10 on the chroma scale, and other deviations from the sphere exist.

field. This seems unhandy to me and is liable to turn up the edges of the little rectangular tabs of color so as to harm or destroy them. I have placed each chart separately in a little manila envelope[12] and have labeled the envelope with the name of the chart enclosed. Furthermore, the protective tissue paper for each chart is preserved by the envelope but is destroyed by the fanning-out of the charts.

As the preparation of these standards involves much hand work, and as the edition is limited, users are urged to exercise reasonable care in preserving them.

Additional colors needed.—A geologist working with the blue and purple beds of the Chinle formation would be handicapped by the lack of these colors on the charts. The color of a 20-foot clay member in the lower Chinle near St. Johns, Arizona, is weak yellow-green. The Morrison formation is variegated. Some Simpson shale[13] from deep wells in West Texas is dusky olive green or very dusky green, not olive. The color of some "green" Permian bentonite[14] lies nearer the blue range than the yellow. The color of the "dull pink shale" member[15] of the Marlow formation is moderate orange pink.

Geologists should make a collection of rock specimens from surface and subsurface comparable with the set of 250 representative soil samples. The colors of these specimens should be determined in Munsell notation by the same methods that the soil scientists used. Then would it not be a good idea for a committee from the American Association of Petroleum Geologists and the Division of Geology and Geography of the National Research Council to coöperate with the committee of soil scientists in a revision of the charts to make them more suitable for geologic field use? The Rice *et al.* text (p. 11) says:

After the standards have been used for some time, it may prove desirable to delete some and add others. Comments from field and laboratory workers will be welcomed.

If standard rock-color charts were available, college courses in stratigraphy and sedimentology might well include training in the accurate description of rock colors.

Graphic representation of rocks.—Most geologists in the Permian basin represent lithologic composition graphically on log strips by means of conventional colors. From 10 to 20 years ago the geological department of the Midwest Refining Company used patterns drawn in India ink to represent lithologic composition, and colors to represent the color of the rocks. This is a useful and effective system.

In 1933 Neil H. Wills and I devised a system that has most of the advantages of the Midwest system as well as some of its own. The saline residues, anhydrite (or gypsum), salt, and polyhalite, are represented by conventional colors of brilliant hues that are seldom or never found in rocks. Thus they are plotted quickly and stand out on graphic logs. The color of saline residues is ordinarily gray and their color changes have less stratigraphic significance than the color changes of clastic or calcareous rocks. The latter are represented as in the Midwest system.

Assuming the existence of easily obtainable rock-color charts, it might be possible after the war also to obtain colored pencils accurately representing the most common hues of sedimentary rocks. A dozen pencils could represent these hues plus the brilliant conventional colors for saline residues. The logs so plotted would bear a closer relation to the geologic reality they represent than do the conventional graphs now in use.

Color dictionary.—The Maerz and Paul dictionary

is primarily intended as a reference for the individual who seeks to relate colors with the names by which they are commonly identified.

[12] Karolton Klasp—$4\frac{5}{8}\times 6\frac{3}{4}$—the American Envelope Company, West Carrollton, Ohio.

[13] Maerz and Paul, p. 71, approx. 24 C 6.

[14] Idem, p. 79, approx. 28 A 2, Smoke Gray.

[15] *Anadarko Basin Field Trip, March 19–20, 1939*, Road Log, 28th Annual Meeting, Amer. Assoc. Petrol. Geol., Oklahoma City (1939), p. 4, Stop I.
Maerz and Paul, p. 29, approx. 3 B 9, Rose Dawn.

It contains

the most extensive range of colors as yet published, together with a list of practically all recorded color names in use up to this time in the English language. Just as the English Dictionary records words and their meanings according to their accepted usage, in the same manner this Dictionary of Color is a record of color words and the particular color sensations they identify as established by consensus of opinion of existing works.

The 56 color plates of this dictionary illustrate 7,056 different colors. The inks used "are reasonably permanent to light and the color plates may be freely exposed."

The introduction, pages 1–13, is recommended as a good practical summary of the subject of color names in general. One sentence is quoted as it helps to explain why rock colors seemingly brilliant in the field so often turn out to be weak when compared with color standards in the laboratory.

Outdoors the general color effect is subdued, especially in cities, where the streets contain much shadow and dark grey, so that by virtue of the unfatigued condition of the eye and of the contrast of the surrounding greyness, the small portions of bright color in hat, dress, window display, or otherwise, always appear of enhanced brilliancy.

To find out the meaning of the number and letter symbols and abbreviations used in the 19-page index of color names at the back of the dictionary one has to scan through many pages of text. A summary of symbols with text-page references placed at the beginning of the index would be helpful.

Munsell color notation.—The numerical scales of lightness, chroma, and hue mentioned in this review together compose the Munsell system of color notation. A small book by A. H. Munsell[16] is an illustrated introduction to his system and to the whole subject of color from the viewpoint of such creative workers in colors as artists, painters, dress designers, or designers of magazine covers and advertizing layouts. A geologist's problem is much simpler: he has only to identify and record rock colors accurately.

The Munsell color notation is a psychological system. Its units are meant to designate equal steps in the sense perception of hue or lightness or chroma. It does have a relation, however, to psychophysical and physical systems of colorimetry: to tristimulus values, and wave lengths, and reflectances. Anyone interested may pursue this aspect of the subject in two issues of the *Journal of the Optical Society of America*[17] and in the references there given.

An interesting history of the Munsell color system by Nickerson,[18] includes a considerable list of references. Booklets by Cleland[19] and Cooper[20] are available.

Munsell color charts (abridged editions) were used in the laboratory determinations of the colors of the 250 soil samples. The Rice *et al.* booklet reports that conversion tables "will soon be available" to permit the "fairly reliable transfer" from the Maerz and Paul dictionary to the Munsell notation or from the Munsell notation to an international coordinate system adopted in 1931. These tables would enable a soil scientist or geologist,

[16] A. H. Munsell, *A Color Notation*, Munsell Color Company (1941). $2. Subtitle: "An Illustrated System Defining All Colors and Their Relations by Measured Scales of Hue, Value, and Chroma." With an introduction by Royal B. Farnum, director, Rhode Island School of Design. 9th ed. (edited and rearranged by A. E. O. Munsell). Cloth. 6×8 inches, 71 pp., frontispiece, 3 pls. in color, 13 text figs., table of luminous reflectances for Munsell values.

[17] Vol. 30, No. 12 (December, 1940) $0.25 a copy. Vol. 33, No. 7 (July, 1943), $0.60 a copy. Both obtainable from Munsell Color Company.

[18] Dorothy Nickerson, "History of the Munsell Color System and Its Scientific Application," *Jour. Optical Soc. America*, Vol. 30, No. 12 (December, 1940), pp. 575–86.

[19] T. M. Cleland, *A Practical Description of the Munsell Color System with Suggestions for Its Use*. Munsell Color Company (1937). $0.45.

[20] F. G. Cooper, *Munsell Manual of Color*. Munsell Color Company (1941). $0.25.

who feels the need of nicer color distinctions, to supplement the system here reviewed by direct reference to the Maerz and Paul dictionary. The Munsell notation also provides an efficient and accurate means of recording nice distinctions of color. To use it the geologist will have to learn to interpolate between the standards as the color scientists do. The lack of standards with chroma between 0.5 and 2, however, is for the geologist a defect of

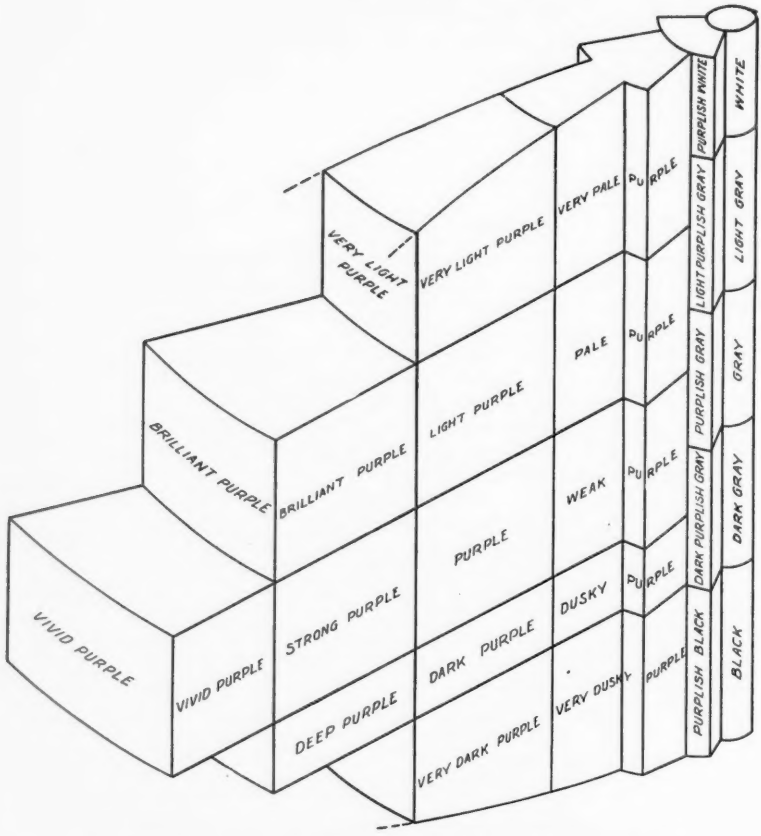


FIG. 2.—Portion of color solid including purples, grays, black, and white (after Rice *et al.*, p. 8).

the *Munsell Book of Color;* it is difficult, for example, to tell by extrapolation from Munsell standards whether a rock is light greenish gray or light bluish gray.

For the present a geologist who needs to describe colors not shown on the soil charts may, if he can afford it, refer to the abridged edition of the *Munsell Book of Color*, supplemented by the 36 conversion charts in Judd and Kelly's paper. These charts give the ranges in Munsell hue, value, and chroma of all the names of the standard subdivisions of the color solid. A few of these subdivisions are illustrated in Figure 2.

Until that happy day when a set of rock-color charts is published, it is recommended that three publications be considered as standard color equipment of the geological laboratories of oil companies and the geological departments of colleges and universities: to-wit,

1. *U. S. Department of Agriculture Miscellaneous Publication No. 425* (Rice, Nickerson, O'Neal, and Thorp),
2. *Munsell Book of Color*, Abridged Edition, Vol. I,
3. *National Bureau of Standards Research Paper No. 1239* (Judd and Kelly).

RECENT PUBLICATIONS

ALASKA

*"Perennially Frozen Ground in Alaska: Its Origin and History," by Stephen Taber. *Bull. Geol. Soc. America*, Vol. 54, No. 10 (New York, October 1, 1943), pp. 1433–48; 22 pls., 13 figs.

AUSTRALIA

"The Genus Lepidocyclina in Victoria," by Irene Crespin. *Proc. Royal Soc. Victoria*, Vol. 55 (N.S.), Pt. II (Melbourne, October 1, 1943), pp. 157–80, Pls. 3–9, Fig. 1.

CALIFORNIA

*"Late Pleistocene Coast Range Orogenesis in Southern California," by Thomas L. Bailey. *Bull. Geol. Soc. America*, Vol. 54, No. 10 (New York, October 1, 1943), pp. 1549–68; 2 pls., 2 figs.

COLOMBIA

*"Distribucion geografica de la formation Guali (Pleistoceno) en una parte del Valle del Alto Magdalena," by Thomas J. Etherington. *Instituto Colombiano de Petroleos Estudio Tecnico 4* (Bogota, December, 1942). 7 pp., 1 map. Contains comments by W. C. Hatfield and J. W. Butler. In Spanish.

GENERAL

*"New Program of Federal Geological Survey Is Streamlined to Needs of Oil Industry," by Hugh D. Miser. *Oil Weekly*, Vol. 111, No. 12 (Houston, November 22, 1943), p. 40.

*"Horizontal Wells May Revolutionize Secondary Recovery," by C. O. Fairbank. *Oil Weekly*, Vol. 111, No. 13 (Houston, November 29, 1943), pp. 11–14; 10 photographs.

*"Determining Probability of Success of Secondary Recovery Operations," by Jo H. Cable. *Ibid.*, pp. 14–20.

*"Use of Fluorescent Surface Surveys and Subsurface Logs to Find Oil," by Tom L. Turner. *Ibid.*, pp. 22–26; 3 figs.

*"Correlation of the Cenozoic Formations of the Atlantic and Gulf Coastal Plain and the Caribbean Region," by C. Wythe Cooke, Julia Gardner, and Wendell P. Woodring. *Bull. Geol. Soc. America*, Vol. 54, No. 11 (New York, November 1, 1943), pp. 1713–22; 1 pl.

*"Oil-Field Flooding Streamlined for War—A Suggestion," by Frederick A. Squires. *Oil and Gas Jour.*, Vol. 42, No. 30 (Tulsa, December 2, 1943), pp. 47–52, 63; 10 figs.

*"Deeper Drilling Prospects in the Mid-Continent," by A. R. Denison. *Petroleum Technology*, Vol. 6, No. 2 (New York, November, 1943). 8 pp., 5 figs. *A.I.M.E. Tech. Pub. 1650.*

*"Education and the Petroleum Industry," by V. C. Illing. *Jour. Inst. Petroleum*, Vol. 29, No. 238 (London, October, 1943), pp. 259–83.

*"Determining Probability of Success of Secondary-Recovery Operations, Part 2, Geological Factors Influencing Secondary Recovery," by Charles R. Fettke, Parke A. Dickey, Douglas Rogers, Jr., Paul D. Torrey, and C. J. Wilhelm. *Oil Weekly*, Vol. 112, No. 1 (Houston, December 6, 1943), pp. 24–30.

*"Determining Probability of Success of Secondary-Recovery Operations. Part 4. Influence of Fluid Saturation on Secondary Recovery of Oil," by Parke A. Dickey. *Oil Weekly*, Vol. 112, No. 2 (December 13, 1943), pp. 36–44.

*"Bibliography of Seismology No. 13, Items 5440–5563, January to June, 1943," by Ernest A. Hodgson. *Pub. Dominion Observatory*, Vol. 13 (Ottawa, 1943), pp. 251–31. Price, $0.25.

GEORGIA-FLORIDA

*"Southeast Georgia-North Florida Area Getting Big Exploration Play," by Don L. Carroll. *Oil Weekly*, Vol. 112, No. 2 (Houston, December, 13, 1943), pp. 46–50; 2 figs.

KANSAS

*"Peace Creek—A Stratigraphic Trap," by Joseph A. Kornfeld. *World Petroleum*, Vol. 14, No. 13 (New York, December, 1943), pp. 38–47; 7 maps and sections, stables.

KENTUCKY

Geology of Union County, Kentucky, by Willard Rouse Jillson. A new book written as a guide for oil and gas operators. Includes areal maps of producing pools. Standard Printing Company, Inc., Louisville 2, Kentucky. Price, $2.50.

MISSISSIPPI

*"Clay County," by Harlan Richard Berquist, Thomas Edwin McCutcheon, and Virginia Harriett Kline. *Mississippi Geol. Survey Bull. 53* (University, 1943). 98 pp., 14 figs., 1 map, 8 pls. of fossils.

NEW MEXICO

*"Permian Type Sections in Central New Mexico," by C. E. Needham and Robert L. Bates. *Bull. Geol. Soc. America*, Vol. 54, No. 11 (New York, November 11, 1943), pp. 1653–68; 2 figs.

TENNESSEE

*"Oil and Gas in Middle Tennessee, with Map of Pools, Columnar Section, Table of Data, and History of Developments," by Kendall E. Born. *Tennessee Div. Geol.* (Nashville, 1943). Paper sheet, 34×22 inches.

TEXAS

*"Geology of the Santiago Peak Quadrangle, Texas," by Gus K. Eifler, Jr. *Bull. Geol. Soc. America*, Vol. 54, No. 10 (New York, October 1, 1943), pp. 1613–44; 5 pls.

*"Frio Discovery in Old Salt Dome Field Is Major Strike," by Don L. Carroll. *Oil Weekly*, Vol. 112, No. 1 (Houston, December 6, 1943), pp. 12–13; 1 fig.

TURKEY

*"Geologic de la region de Maras-Gaziantep," by V. Stchepinsky. *Maden Tetkik ve Arama*, Sene 8, Sayi 1/29 (Ankara, 1943), pp. 116–25; geological map and fossil list. In French.

*"Micro-Fauna of the Upper Cretaceous and Tertiary Sections (Arabian Facies) in the Urfa and Gaziantep Regions (Southern Turkey)," by S. W. Tromp. *Ibid.*, pp. 134–41; chart. In English.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 1 (JANUARY, 1944), PP. 139-168

THE ASSOCIATION ROUND TABLE

MEMBERSHIP APPLICATIONS APPROVED FOR PUBLICATION

The executive committee has approved for publication the names of the following candidates for membership in the Association. This does not constitute an election but places the names before the membership at large. If any member has information bearing on the qualifications of these nominees, he should send it promptly to the Executive Committee, Box 979, Tulsa 1, Oklahoma. (Names of sponsors are placed beneath the name of each nominee.)

FOR ACTIVE MEMBERSHIP

Alcuin John Krumholz, Arcadia, Wis.
Hollis D. Hedberg, Louis Sass, John G. Douglas

Dan Landry Marshall, New Orleans, La.
G. W. Schneider, M. N. Broughton, B. E. Bremer

Ralph Harold McKinlay, Wichita Falls, Tex.
S. A. Thompson, William W. Clawson, Fred H. Wilcox

Leonard Frederick Schombel, Bakersfield, Calif.
M. G. Edwards, Arne Junger, H. R. Thornburgh

H. Edgar Summerford, Tulsa, Okla.
Sherwood Buckstaff, A. C. Trowbridge, R. V. Hollingsworth

FOR ASSOCIATE MEMBERSHIP

Thomas Grayson Moran, Los Angeles, Calif.
Wendell P. Woodring, U. S. Grant, IV, M. N. Bramlette

Mary Louise Treadwell, Tulsa, Okla.
J. V. Howell, Charles Nevin, Katherine V. W. Palmer

FOR TRANSFER TO ACTIVE MEMBERSHIP

Wilson Morrow Laird, Grand Forks, N. Dak.
O. A. Seager, D. L. Blackstone, Jr., George R. Downs

ASSOCIATION COMMITTEES

EXECUTIVE COMMITTEE

A. RODGER DENISON, *chairman*, Amerada Petroleum Corporation, Tulsa, Oklahoma
ROBERT E. RETTGER, *secretary*, Sun Oil Company, Dallas, Texas
FRITZ L. AURIN, Southland Royalty Company, Fort Worth, Texas
ROBERT W. CLARK, Western Gulf Oil Company, Los Angeles, California
CAREY CRONEIS, University of Chicago, Chicago, Illinois

REPRESENTATIVE ON DIVISION OF GEOLOGY AND GEOGRAPHY NATIONAL RESEARCH COUNCIL: M. G. CHENEY (1946)

REPRESENTATIVES ON COMMISSION ON CLASSIFICATION AND NOMENCLATURE OF ROCK UNITS

MONROE G. CHENEY (1944) JOHN G. BARTRAM (1945) C. W. TOMLINSON (1946)

FINANCE COMMITTEE

IRA H. CRAM (1944) JOSEPH E. POGUE (1945) CHARLES E. YAGER (1946)

TRUSTEES OF REVOLVING PUBLICATION FUND

GLENN C. CLARK (1944) W. B. WILSON (1945) WALLACE E. PRATT (1946)

TRUSTEES OF RESEARCH FUND

O. G. BELL (1944) W. R. BERGER (1945) CLARENCE L. MOODY (1946)

BUSINESS COMMITTEE

O. L. BRACE (1944), *chairman*, 803 Second National Building, Houston, Texas

J. D. AIMER (1945)
KARL ARLETH (1944)
GORDON I. ATWATER (1945)
FRITZ L. AURIN (1944)
W. C. BEAN (1944)
R. C. BOWLES (1944)
LESLIE BOWLING (1944)
RICHARD W. CAMP (1945)
T. C. CASH (1945)
OSCAR R. CHAMPION (1945)
ROBERT W. CLARK (1944)
R. CLARE COFFIN (1945)
EDWIN G. COLE (1945)
CAREY CRONEIS (1944)
A. R. DENISON (1945)
REX P. GRANT (1945)
S. G. GRAY (1945)
DARSIE A. GREEN (1945)
M. GORDON GULLEY (1945)
DILWORTH S. HAGER (1944)
T. C. HIESTAND (1944)
MASON L. HILL (1945)
WILLIAM C. IMBT (1945)
J. HARLAN JOHNSON (1944)
ELISHA A. PASCHAL (1946)
JAMES C. KIMBLE (1945)
ROBERT N. KOLM (1944)
MAX L. KRUEGER (1944)
CHARLES S. LAVINGTON (1945)
TOM MCGLOTHLIN (1945)
W. B. MOORE (1945)
PHILIP E. NOLAN (1945)
ROBERT E. RETTGER (1944)
J. G. SPRATT (1945)
HENRYK B. STENZEL (1944)
L. W. STEPHENSON (1944)
HUGH A. TANNER (1945)
LUCIAN H. WALKER (1945)
LEWIS G. WEEKS (1945)
C. E. YAGER (1945)

COMMITTEE FOR PUBLICATION

J. V. HOWELL (1945), *chairman*, 912 Philtower Building, Tulsa, Oklahoma

1944	1945	1946
ALFRED H. BELL	JOSEPH L. BORDEN	GORDON I. ATWATER
JOHN W. INKSTER	KENDALL E. BORN	CHARLES BREWER, JR.
ROBERT N. KOLM	R. L. CLIFTON	C. E. DOBBIN
HANS G. KUGLER	CLIFTON L. CORBETT	JAMES R. DORRANCE
JERRY B. NEWBY	LYNN K. LEE	EARL P. HINDES
PAUL H. PRICE	E. RUSSELL LLOYD	GEORGE S. HUME
J. D. THOMPSON	H. E. MINOR	GEORGE D. LINDBERG
HENRY N. TOLER		A. C. WRIGHT

RESEARCH COMMITTEE

M. G. Cheney (1945), *chairman*, Coleman, Texas
W. C. Krumbein (1946), *vice-chairman*, Washington, D. C.

1944	1945	1946
Ben B. Cox	N. Wood Bass	Alfred H. Bell
George C. Gester	Ronald K. DeFord	Walter R. Berger
W. S. W. Kew	M. G. Edwards	Paul E. Fitzgerald
D. Perry Olcott	Winthrop P. Haynes	Ralph A. Liddle
Wendell P. Rand	Philip B. King	W. H. Twenhofel
F. W. Rolshausen	A. I. Levorsen	Warren B. Weeks
F. M. Van Tuyl	Paul H. Price	
Paul Weaver		

GEOLOGIC NAMES AND CORRELATIONS COMMITTEE

John G. Bartram (1945), *chairman*, Stanolind Oil and Gas Company, Tulsa, Oklahoma

1944	1945	1946
Monroe G. Cheney	Robert I. Dickey	Gordon I. Atwater
Robert H. Dott	Hugh D. Miser	Darsie A. Green
Wayne V. Jones	Raymond C. Moore	Ralph W. Imlay
W. Armstrong Price	Norman L. Thomas	C. W. Tomlinson
Horace D. Thomas		
Warren B. Weeks		

SUB-COMMITTEE ON CARBONIFEROUS

M. G. Cheney (1945), *chairman*, Coleman, Texas

Robert H. Dott	Raymond C. Moore	C. W. Tomlinson
	Horace D. Thomas	

SUB-COMMITTEE ON POST-CRETACEOUS

W. Armstrong Price (1944), *chairman*, Box 1860, Corpus Christi, Texas

Gordon I. Atwater	Henry V. Howe	Watson H. Monroe
Thomas L. Bailey	Wayne V. Jones	E. A. Murchison, Jr.
Marcus A. Hanna	Tom McGlothlin	Warren B. Weeks

SUB-COMMITTEE ON MESOZOIC

Ralph W. Imlay, *chairman*, U. S. Geological Survey, Washington, D. C.

C. E. Dobbin	Henry J. Morgan	G. D. Thomas
L. R. McFarland	Gayle Scott	Norman L. Thomas

COMMITTEE ON APPLICATIONS OF GEOLOGY

Paul Weaver, *chairman*, Gulf Oil Corporation, Houston, Texas
Henry C. Cortes (1944), *vice-chairman, geophysics*, Dallas, Texas
Gayle Scott (1945), *vice-chairman, paleontology*, Fort Worth, Texas

1944	1945	1946
George S. Buchanan	M. M. Leighton	R. M. Barnes
Wesley G. Gish	Paul H. Price	J. Brian Eby
Kenneth K. Landes		H. S. McQueen
		R. A. Steinmayer

MEDAL AWARD COMMITTEE

A. Rodger Denison, *ex officio* and *chairman*, Amerada Petroleum Corporation, Tulsa, Oklahoma
J. Harlan Johnson, *ex officio*, president of S.E.P.M.
R. D. Wyckoff, *ex officio*, president of S.E.G.

1944	1945	1946
H. B. Fuqua	G. Clark Gester	Frank R. Clark
Ira H. Cram	Darsie A. Green	Raymond F. Baker
Hugh D. Miser	Wallace C. Thompson	James A. MacDonell

SPECIAL COMMITTEES

COMMITTEE ON COLLEGE CURRICULA IN PETROLEUM GEOLOGY

FREDERIC H. LAHEE, *chairman*, Sun Oil Company, Dallas, Texas

L. T. BARROW
WALTER R. BERGER
HAL P. BYBEE
IRA H. CRAM
CAREY CRONEIS
WINTHROP P. HAYNES
K. C. HEALD
K. K. LANDES
JOHN D. MARR
E. K. SOPER
W. T. THOM, JR.

NATIONAL SERVICE COMMITTEE

KENNETH C. HEALD, *chairman*, The Gulf Companies, Pittsburgh, Pennsylvania

FRITZ L. AURIN
A. E. BRAINERD
IRA H. CRAM
GEORGE M. CUNNINGHAM
THORNTON DAVIS
RONALD K. DEFORD
JOHN O. GALLOWAY
M. GORDON GULLEY
W. DOW HAMM
W. B. HEROY
HAROLD W. HOOTS
EDWARD A. KOESTER
PHIL F. MARTYN
L. F. MCCOLLUM
DEAN A. MCGEE
CLARENCE L. MOODY
PAUL H. PRICE

DISTINGUISHED LECTURE COMMITTEE

JOHN L. FERGUSON, *chairman*, Amerada Petroleum Corporation, Tulsa, Oklahoma

LON D. CARTWRIGHT, JR. JOHN W. INKSTER W. J. HILSEWECK FRED H. MOORE

COMMITTEE ON SOUTH AMERICAN GEOLOGY

A. I. LEVORSEN, *chairman*, 221 Woodward Boulevard, Tulsa, Oklahoma

---

MEMBERS IN MILITARY AND GOVERNMENT SERVICE

F. L. AURIN[1]
Fort Worth, Texas

A list of the members of the American Association of Petroleum Geologists now serving in the Armed Forces and of those members of our Association who are working in a civilian capacity for our Government or for Government agencies in Allied countries, has been compiled by Fritz L. Aurin of our national service committee.

Although the list is as complete as the information of the committee can make it, doubtless there are omissions.

The list furnishes as many as possible of the present post-office addresses of our friends and associates who have undertaken the more grim and dangerous duties in the war. We want the fellow members of these men to know how to reach them with a letter; to give them a touch of familiar places and people as well as activities, to allow them to know that they have not been forgotten and that many are concerned with their welfare. We want them to know that we are proud of them. ***Write to them.***

K. C. HEALD, *chairman*
National service committee

[1] Association national service committee.

MEMBERS OF AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS SERVING IN ARMED FORCES OF UNITED STATES AND ALLIED COUNTRIES

(December 6, 1943)

Name	*Last Home Address* (*Military Address*)	*Rank*	*Branch of Service*
Abbey, Gerald Ellsworth	Rt. 1, Platte City, Mo. (Co. A, 653rd Eng. Bn. (Topo), Camp Claiborne, La.)		Corps of Eng.
Achning, Walter J.	Rt. 1, Box 51, Colorado Springs, Colo.	Capt.	Army Air Corps
Adams, Clyde B.	93 Paul Revere Rd., Needham Heights, Mass.		U. S. Army
Adams, Robert Wiley	Box 664, Reseda, Calif. (Naval Tng. Indoctrination School, Univ. of Arizona, Tucson, Ariz.)		U. S. Navy
Addington, Harold W.	(4th Prov. Tng. Regt., Camp Claiborne, La.)	Lt.	Corps of Eng.
Akers, Wilburn Holt	1029 S. W. 28th St., Oklahoma City, Okla. (A.P.O. 34, c/o P.M., New York, N. Y.)	Lt.	Field Artillery
Alcorn, James M.	5527 Richard Ave., Dallas, Tex.		Army Air Corps
Allen, William Hammond	Shell Oil Co., Inc., Box 1509, Midland, Tex. (A.P.O. 726, c/o P.M., Seattle, Wash.)	Lt.	Infantry
Allen, William Odis, Jr.	1331 E. 26th St., Tulsa, Okla.	Lt.	Tank Destroyer Bn.
Andersen, Harold V.	2104 Park, Houston 6, Tex. (A.P.O. 184, c/o P.M., Los Angeles, Calif.)	Lt.	Corps of Eng.
Anderson, Frank Marion	1635 Pine St., Dallas, Tex. (818 Malcolm Ave., Los Angeles 24, Calif.) (234,483)	Ens.	U. S. Navy
Anderson, James Burt	415 W. Lomita Ave., Glendale, Calif. (Eng. School, Rm. 15, Flagler Hall, Fort Belvoir, Va.)	Lt.	Corps of Eng.
Anderson, Kenneth C.	4042 Warwick Blvd., Kansas City, Mo. (Camp Claiborne, La.)	Lt.	
Anderson, Oscar S., Jr.	Big Four Petr. Co., Box A, Oilton, Okla. (c/o Fleet P.M., San Francisco, Calif.)	Lt.	U. S. Navy
Anderson, Thomas C. I.	2250 Parnell Ave., W. Los Angeles, Calif.	Cpl.	Coast Artillery
Andrau, Evert W. K.	Box 2408, Houston 1, Tex. (A.P.O. 929 c/o Postmaster, San Francisco, Calif.)	Capt.	Army Air Corps
Anisgard, Harry W.	503 W. 124th St., New York, N. Y.		U. S. Army
Arick, Millard B.	Midland, Tex. (A.P.O. 634, c/o P.M., New York, N. Y.)	Lt.	Army Air Corps
Arnold, Harry H., Jr.	131 Seventh Ave., Clarion, Pa. (Engineer School, Fort Belvoir, Va.)	Major	Corps of Eng.
Arper, William B., Jr.	c/o Mrs. W. B. Arper, 603 Glenmar, Monroe, La. (A.S.N. 37577320, Reception Center, Ft. Snelling, St. Paul, Minn.)	Pvt.	U. S. Army
Austin, Robert Burton	631 W. 59th St., Kansas City, Kan. (551st Eng. Bn. (Hv. P. & N), Camp Gordon, Ga.)		Corps of Eng.
Bachman, Ford F.	501 Welch, Houston, Tex. (O-375608, A. C. Detachment, G.A.A.F., Greenwood, Miss.)	Lt.	Army Air Corps
Back, Denys H.	3918 Brandt, Houston 6, Tex.		
Bailey, John James	Box 1814, Midland, Tex. (6th Photo Sqn., Peterson Field, Colorado Springs, Colo.)	Pvt.	Army Air Corps
Baldwin, E. B.	3609 Porter Ave., El Paso, Tex.	Lt.	U. S. Navy
Ballantyne, R. S., Jr.	1530 Van Ness Ave., S., Los Angeles, Calif.	Lt.	Army Air Corps
Ballard, James L.	2811 S. Cincinnati, Tulsa 5, Okla. (Navy 250, F.P.O., San Francisco, Calif.)	Capt.	U. S. Marines
Bard, Richards J.	Bryn Mawr, Pa.	Major	U. S. Army
Barnes, Sydney U.	1720½ N. Gower, Hollywood, Calif. (A.P.O. 4121, c/o P.M., New York, N. Y.)	Lt.	Field Artillery
Barnett, John F., Jr.	Palacios, Tex. (2nd Bn., 5th Inf., Camp Van Dorn, Miss.)	Lt.	
Barney, Arthur Y.	Box 873, Charleston, W. Va. (Dept. Int. Service, A.A.F. Hdqtrs. Annex 1, Gravelly Point, Washington, D. C.)	Capt.	Army Air Corps
Barry, John O.	Plaquemine, La. (13th F.A. Obsn. Bn., c/o P.M., Elkins, W. Va.)	Lt.	Field Artillery
Bartle, Glenn G.	5604 Holmes St., Kansas City, Mo. (Anti-Aircraft Tn. & Testing Field, Dam Neck, Va.)	Lt.	U. S. Navy
Bartley, Jerald Howard	Box 2053, Glen Rose, Tex. (175,803, Armed Guard Center, U. S. Naval Station, New Orleans 14, La.)	Lt.	U. S. Navy

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Barwick, John S.	703 Union National Bank Bldg., Wichita, Kan. (Glasgow Air Base, Glasgow, Mont.)	Lt.	Army Air Corps
Bateman, Andrew F., Jr.	227 E. 4th St., Loveland, Colo. (922nd Eng. Regt., Geiger Field, Wash.)	Lt.	Corps of Eng.
Bates, Charles C.	Rt. 2, Rockton, Ill. (Scripps Inst. of Oceanography, La Jolla, Calif.)	Lt.	Army Air Corps
Batla, Thomas W.	Bellville, Tex.		U. S. Army
Baxter, John C.	Gulf Res. & Devel. Co., Box 2038, Pittsburgh, Pa. (A.P.O. 4774, c/o P.M., New York, N. Y.)	Capt.	Coast Artillery
Baysinger, Eugene M.	Box 210, Lake Charles, La. (911th Eng. Hdqtrs. Co. (AF), MacDill Field, Fla.)	Lt.	Corps of Eng.
Beatty, Robert M.	Park Lane Apts., Apt. 1501, 5701 Jackson, Houston, Tex. (6th Photo Sq., Peterson A.A.F., Colorado Springs, Colo.)	Lt.	Army Air Corps
Becker, Leroy Everett	537 Lincoln St., Princeton, Ill. (O-1179466, Hdq. & Hdq. Btry, 137th F.A. Group, Camp Gruber, Okla.)	Lt.	Field Artillery
Becker, Robert More	224 S. 14th, Chickasha, Okla. (18096424, Sqn. G, Div. 15, T.S., A.A.F.T.C., Yale Univ., New Haven, Conn.)	Lt.	Army Air Corps
Becker, Theodore G.	224 S. 14th, Chickasha, Okla.	Lt.	U. S. Army
Beckwith, R. H.	1421 Sheridan St., Laramie, Wyo. (Hdqtrs., Amphibious Corps, Pac. Fleet, Camp Elliott, San Diego, Calif.)	Capt.	Marine Corps
Bell, Olin G.	5519 Jackson St., Houston, Tex. (U. S. Army Air Base, Colorado Springs, Colo.)	Major	Army Air Corps
Bemis, Harold C.	1090 W. Beverly Blvd., Whittier, Calif.		U. S. Army
Bennett, Robert T.	Mt. Vernon, Iowa (0-1011708, Student Officers Group, Armored Command School, Fort Knox, Ky.)	Lt.	Armored Force
Berger, Walter R., Jr.	3920 Potomac Ave., Fort Worth, Tex. (A.P.O. 828, c/o P.M., New Orleans, La.)	Capt.	Ordnance Corps
Bescher, Earl, Jr.	3803 B Speedway Ave., Austin, Tex. (Air Force Classification Center, Santa Ana Army Air Base, Santa Ana, Calif.)	Lt.	Army Air Corps
Birk, Ralph A.	Bridwell Oil Co., 814 City Natl. Bank Bldg., Wichita Falls, Tex. (772nd MP Bn., Northwestern Sector P.O., Fort Lewis, Wash.)	Lt. Col.	Military Police
Blair, Robert William	551 Marion St., Denver, Colo. (477th Bomb Sqn. (M), Barksdale Field, La.) (O-424092)	Capt.	Army Air Corps
Bleakley, Alfred Bishop	1203 S. Utica, Tulsa, Okla. (Naval Avn. Tech. Tng. School, Norman, Okla.)	Ens.	U. S. Navy
Boling, Kenneth George	1903 S. A St., Elwood, Ind. (36376864, 654th Eng. Hdq. Co., Camp McCoy, Wis.)	Pvt.	Corps of Eng.
Bonar, Robert Emerson	Box 532, Denton, Tex. (A.P.O. 709-2 c/o P.M., San Francisco, Calif.)	Sgt.	Army Air Corps
Booth, William Norfolk	459 High Dr., Laguna Beach, Calif. (Base Hq. Sqn., M.C.A.S., El Toro, Calif.)	Lt.	Marine Corps
Borax, Eugene	3843 City Terrace Dr., Los Angeles, Calif. (O-862566, 6th Photo Sqn., Photo Compilation, Peterson Field, Colorado Springs, Colo.)	Lt.	Army Air Corps
Bosco, Francis Neal	2166 S. Washington, Denver, Colo. (779 Eng. Petr. Distn. Co., Camp Claiborne, La.)		Corps of Eng.
Bowsher, Arthur Leroy	Box 1822, Pampa, Tex. (O-1115848, 780th Eng. Petr. Dist. Co., E.U.T.C., 5th Proving Tng. Regt., Camp Claiborne, La.)	Lt.	Corps of Eng.
Boyle, James Philip, Jr.	405 N. W. 22nd St., Oklahoma City, Okla. (Bldg. 801, U. S. Naval Air Sta., Jacksonville, Fla.)	Ens.	U. S. Navy
Bradbury, Albert Edward	Box 335, Evanston, Wyo. (4 E. 82nd St., New York, N. Y.)	Lt.	Army Air Corps
Brazil, James Joseph	c/o John Wright, Cragmere Park, Box 363, Mahwah, N. J.	Lt.	U. S. Navy
Breed, Edgar R., Jr.	Shell Oil Co., Inc., Box 476, Centralia, Ill. (c/o F.P.O., San Francisco, Calif.)	Lt.	U. S. Navy

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Briggs, Colver R.	533 S. Arden Blvd., Los Angeles, Calif. (A.A.F.T.D., U.C.L.A., Class 5, Los Angeles, Calif.)	Lt.	Army Air Force
Britt, Harry M., Jr.	809 Jackson St., Amarillo, Tex.		Marine Corps
Bronner, Finn Eyolf	c/o Norwegian Embassy, Washington, D. C. (A.P.O. 512, c/o P.M., New York, N. Y.)	Capt.	U. S. Army
Brown, Augustus Bart	Mudge Oil Co., Gulf States Bldg., Dallas, Tex. (Naval Section Base, Cockspur Is., Savannah, Ga.)	Ens.	U. S. Navy
Brown, J. Earle	5900 Merrymount Rd., Fort Worth, Tex. (Army Air Base, Pueblo, Colo.)	Major	Army Air Corps
Brown, Silas C.	Box 408, Lawrence, Kan. c/o Fleet P.O., New York, N. Y.)	Ens.	U. S. Navy
Browne, Richard Vernon	Iraq Petr. Co., Box 309, Haifa, Palestine	Lt.	British Army
Brundall, Laurence	1701 Rosario, Laredo, Tex. (Photo Interpretation School, Naval Air Sta., Anacostia, D. C.)	Ens.	U. S. Navy
Bryan, Carl L.	2405 Isabella Ave., Houston, Tex.	Lt.	U. S. Navy
Buehner, John Hubert	521 S. 8th St., Vandalia, Ill. (321st Fighter Sqn., 326 Fighter Grp., Westover Field, Mass.)	Lt.	Army Air Corps
Buie, Bennett Frank	Box 951, Warrenton, Va. (Rm. 3731, Munitions Bldg., Washington, D. C.)	Lt.	U. S. Army
Burchard, Frederic L.	5929 Goodwin Ave., Dallas, Tex. (A.A.F.A.F.S., Big Spring, Tex.)	Lt.	Army Air Corps
Burke, James Dan	404 Frank Ave., Lufkin, Tex.		Marine Corps
Burkhead, Wayne Z.	Clemons, Iowa (A.A.F.A.I.S., Harrisburg, Pa.)	Lt.	Army Air Force
Burt, Roy Allen	Burlington Oil Co., 1101 Burlington Ave., N. Kansas City, Mo. (Transportation Dept., Huntsville Arsenal, Huntsville, Ala.)	Lt. Col.	U. S. Army
Bush, Robert Ewell	1726 Marshall St., Houston, Tex. (Btry. C, 31st Bn., F.A.R.T.C., Fort Sill, Okla.)	Lt.	Field Artillery
Butcher, Seldon D.	4 Lakeside Blvd., Wichita 2, Kan. (Specialist Reserve, Eng. Tng. Center, Camp Claiborne, La.)	Capt.	Corps of Eng.
Byers, John W.	511 W. Chestnut St., Denison, Tex. (36 Patton Ave., Dayton, Ohio)	Lt.	U. S. Army
Campbell, John M.	Box 278, Laredo, Tex.	Lt.	U. S. Navy
Campbell, William Robt.	418 Thelma Dr., San Antonio, Tex. (Military Censorship Det., Fort George G. Meade, Md.)	Lt.	U. S. Army
Campo, Henry Andrew	615 W. 9th St., Tulsa, Okla. (Dist. Eng. Office, Panahou Campus, Honolulu, T. H.)	Lt.	Corps of Eng.
Cardwell, Wm. Henry	812 Cypress St., Orange, Tex. (c/o F.P.O., San Francisco, Calif.)	Ens.	U. S. Navy
Cantrell, Ralph B.	2001 Ninth St., Lubbock, Tex. (8 N.D., Deperming Sta., New Orleans, La.)	Deck Officer	U. S. Navy
Carter, George R.	Gulf Oil Corp., Box 1150, Midland, Tex. (Hq. & Hq. Sqn., Photo Avn. Dept., A.A.F.S.A.T., Orlando, Fla.)	S/Sgt.	Army Air Corps
Cartwright, Weldon E.	2521 Wabash Ave., Fort Worth, Tex. (Armed Guard Center, Naval Receiving Station, 1st Ave. & 52nd St., S. Brooklyn, N. Y.)		U. S. Navy
Cast, Richard Frederick	3824 Randolph St., Lincoln, Neb. (F.A. Officers Candidate School)		Field Artillery
Casteel, S. H.	Trust Dept., First Natl. Bank, Fort Worth, Tex.	Lt. Com.	U. S. Navy
Chaddick, Wm. M., Jr.	Plano, Tex. (1000th Guard Sqn., Brooks Field, Tex.)	Pvt.	Army Air Force
Chambers, Robert J.	1918 Oakdale, Houston, Tex. (A.P.O. 76, Camp A.P. Hill, Va.)	Capt.	Infantry
Champion, Joe A.	111 E. Elizabeth St., Brownsville, Tex. (8th Antisubmarine Sqn., 36th St. Airport, Miami, Fla.)	Lt.	Army Air Force
Chappuis, Louis C.	437 S. Hill St., Los Angeles, Calif. (Air Intelligence School, Miami Beach, Fla.)	Capt.	Army Air Force
Cheesman, Beynon Sale	157 Merrick St., Shreveport 57, La.	Lt.	U. S. Army
Christie, Robert S.	Amerada Petr. Corp., Box 1348, Fort Worth 1, Tex.	Capt.	U. S. Army
Clark, James Tate	Phillips Petr. Co., Corpus Christi, Tex. (Naval Tng. School, Tucson, Ariz.)	Ens.	U. S. Navy
Clark, William A., Jr.	225 E. Rich St., Norman, Okla. (U.S.N.A.T.T.C., Norman, Okla.)		U. S. Navy

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Clarke, Robert L.	Box 1245, Midland, Tex. (A-V(P), Naval Tng. School, Harvard Univ., Cambridge, Mass.)	Lt.	U. S. Navy
Clarkson, Wm. Geo., Jr.	224 W. Avenue A, San Angelo, Tex. (LCI(L) 349, c/o F.P.O., New York, N. Y.)	Ens.	U. S. Navy
Clinkscales, Albert S.	904 Concord Bldg., Oklahoma City, Okla. (50 Belle Isle Ct., 31 Venetian Way, Belle Isle, Fla.)	Major	Army Air Force
Cogen, William Maurice	c/o Benjamin Cogen, 1079 S. Odgen Dr., Los Angeles, Calif. (4th Air Force, 180 New Montgomery St., San Francisco, Calif.)	Lt.	Army Air Force
Coil, Fay	Box 510, Midland, Tex. (A.A.A.S.A.W. Dept., Camp Davis, N.C.)	Capt.	Field Artillery
Coldwell, Charles Hatton	1204 W. 10th St., Cisco, Tex. (F.P.O., San Francisco, Calif.)	Lt.	U. S. Navy
Colle, Jack Overton	1970 S. Clayton, Denver, Colo. (Base Photo Section, Army Air Base, Richmond, Va.)		Army Air Force
Colton, Howard Franklin	937 Milam Bldg., San Antonio, Tex. (McDill Field, Tampa, Fla.)	Lt.	Army Air Corps
Conselman, Frank B.	144 N. Clifton Ave., Wichita, Kan. (Appointment & Procurement, Ellington Field, Tex.)	Major	Army Air Corps
Conway, Wm. Palen, Jr.	Blue Mill Road, Green Village, N. J. (A.P.O. 719, San Francisco, Calif.)	Major	Army Air Force
Conwell, Cleland N.	Idaho Springs, Colo. (c/o F.P.O., San Francisco, Calif.)	Ens.	U. S. Navy
Cooke, Henry Clay	407 W. Thirty-Second St., Austin, Tex. (Construction Bn., Overseas)		U. S. Navy
Cooley, Ralph S.	17 Hawthorne Rd., Bradford, Pa. (c/o P.M., San Francisco, Calif.)	Lt.	U. S. Navy
Cooper, C. Harrison	240 N. Yale, Wichita, Kan. (A.P.O. 7, Camp San Luis Obispo, Calif.)	Capt.	Field Artillery
Cooper, James Blair	805 E. 9th, Winfield, Kan. (North Africa)	Pvt.	Corps of Eng.
Corey, George Simpson	c/o W. H. Corey, Box 126, Osceola, Wis. (A.P.O. 708, c/o P.M., San Francisco, Calif.)	Lt.	Army Air Corps
Corman, Hyman	1401 Peabody Ave., Dallas, Tex. (A.P.O. 661, c/o P.M., New Orleans, La.)	Pvt.	U. S. Army
Corning, Leavitt, Jr.	410 Eldon Rd., San Antonio, Tex. (A.P.O. 650, c/o P.M., New York, N. Y.)	Lt.	U. S. Army
Cortes, Henry C., Jr.	4328 Windsor Parkway, Dallas, Tex. (3549 Hertford Pl., N.W., Washington, D. C.)	Ens.	U. S. Navy
Couser, Chester Wendell	Apt. 3, 3916 N. 5th St., Arlington, Va. (O-258798, Off. Asst. Chief Air Int., Rm. G-721, A.A.F. Annex 1, Gravelly Point, D. C.)	Major	Army Air Corps
Covington, Jerry	1602 Shafter, San Angelo, Tex.		U. S. Navy
Cox, Benjamin Burton	Rm. 1141, 26 Broadway, New York, N. Y. (O-924094, Desert & Tropic Section, Arctic, Desert and Tropic Information Center, 25 Broad St., New York 4, N. Y.)	Major	Army Air Force
Cox, Harris J.	Western Geophysical Co., 902 Mellie Esperson Bldg., Houston, Tex. (F.P.O. 131, San Francisco, Calif.)	Lt.	U. S. Navy
Cox, Robert T.	703 S. Daugherty St., Eastland, Tex. (310th C.A., Barrage Balloon Bn., 118th & Doty, Hawthorne, Calif.)	Lt.	Coast Artillery
Cox, Welsy Philip	7705 Military Dr., Dallas, Tex. (Asst. Military Attache, U. S. Embassy, Bogota, Colombia, S.A.)	Capt.	U. S. Army
Crickmay, Geoffrey W.	48 Hubinger St., New Haven, Conn. (U. S. Bur. of Ships, Washington, D. C.)	Lt.	U. S. Navy
Cross, Charles Mumaw	1900 Adeline Dr., Burlingame, Calif. (Ordnance Sect., Hdqtrs., Armored Force, Fort Knox, Ky.)	Lt. Col.	Ordnance Corps
Crowell, John Head	7415 Lynnhurst St., Chevy Chase, Md. (192,449, Bur. of Ships, Navy Dept., Washington, D. C.)	Lt.	U. S. Navy
Curran, John F.	2700 Santa Anita Ave., Altadena, Calif.		U. S. Navy
Curtis, Lawrence W.	514 Stewart Rd., Columbia, Mo. (A.P.O. 632, c/o P.M., Miami, Fla.)	Lt.	Army Air Corps
Cuyler, Robert H.	1216 W. 22nd St., Austin, Tex. (San Antonio Avn. Cadet Center, Pre-Flight School, San Antonio, Tex.)	Lt.	Army Air Corps
Dahl, Arnold C.	337 S. Rutan, Wichita, Kan. (O.T.S.-E.U.T.C., Camp Claiborne, La.)	Lt.	Corps of Eng.
Dake, Laurence F.	1106 Main St., Rolla, Mo. (Ellington Field, Tex.)	Pvt.	Army Air Force

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Damon, Frederic T.	209 Turley Ave., Council Bluffs, Iowa (Naval Air Station, Corpus Christi, Tex.)	Ens.	U. S. Navy
Dana, Drexler	Newton, Ill. (A.P.O. 887, New York, N. Y.)	Major	Corps of Eng.
Daniel, Edgar James	c/o Messrs. Grindlay & Co., Bankers, Bombay, India	Lt.	British Army
Daubert, Charles A.	2102 W. Kings Highway, San Antonio, Tex.	Capt.	Army Air Force
David, Max	Box 1657, Midland, Tex.		U. S. Navy
Davies, Jack W.	Halliburton Oil Well Cementing Co., 626 Waggoner Bldg., Wichita Falls, Tex. (Alcan Highway)	Lt.	Corps of Eng.
Davis, Flavy Eugene	3426 Wylie Dr., Houston, Tex.	Ens.	U. S. Navy
Davis, Gene O.	9715 E. 16th St., Independence, Mo. (17098955, Bks. 37-43K, Goodfellow Field, San Angelo, Tex.)	Cadet	Army Air Force
Davis, Lon, Jr.	Floydada, Tex. (Rm. 25, B.O.O.Q., Naval Air Sta., St. Simons Is., Ga.)	Ens.	Naval Air Corps
Day, James R.	Apt. 29, Meewood Apt., 2511 Harney, Omaha, Neb. (662nd M.P.E.G. Co., Fort Custer, Mich.)	Lt.	Military Police
Dean, D. P.	W. T. Waggoner Bldg., Fort Worth, Tex.	Capt.	Corps of Eng.
Decker, Willis M.	Goddard, Kan.(c/o F.P.O., San Francisco, Calif.)	Ens.	U. S. Navy
DeGoes, Louis Lellanne	4661 Pickford St., Los Angeles, Calif.	Lt.	Ferry Command
DeLong, James A.	637 W. Ford St., Shawnee, Okla. (c/o F.P.O., N.Y.C.)	Ens.	U. S. Navy
Denman, Cedric E.	3115 Broadway, Great Bend, Kan. (A.P.O. 12220, New York, N. Y.)	Capt.	U. S. Army
Deputy, P. R.	1035 N. Edgefield, Dallas, Tex. (O-913821, Hdqtrs. 5th Photo Recon. Grp., Peterson Field, Colorado Springs, Colo.)	Capt.	Army Air Force
Deuth, Martin John	Box 1509, Midland, Tex.		U. S. Army
D'Evelyn, Morton N.	520 Warren Rd., San Mateo, Calif. (Camp Claiborne, La.)	Lt.	Corps of Eng.
Dickerson, Charles H.	Hotel Premier, Crowell, Tex. (Brooks Field, San Antonio, Tex.)	Pvt.	Army Air Force
Diemer, Raymond A.	205 Roosevelt Ave., Robinson, Ill. (38214412, Prov. Co. F., 3205 SCSU, Syracuse Univ., Syracuse, N.Y.)	T-5	Corps of Eng.
Dinsmoor, C. G.	2111 Kings Highway, San Antonio, Tex. (Hq. 799th AAA Bn., Camp Haan, Calif.)	Capt.	Coast Artillery
Doell, Edward C.	Standard Oil Co. of Calif., Bin XX, Taft, Calif. (42-3 F St., 11-C Camp Taft, Calif.)		U. S. Army
Dorreen, James Moore	34 Rawiri St., Kaiti, Gisborne, N.Z. (Prisoner of War)		
Doshier, Achille Wicks	827 Carolina, Amarillo, Tex. (Co. B, 30th Engrs., Ft. Belvoir, Va.)		Corps of Eng.
Dougherty, William E.	402 N. Pecos, Midland, Tex. (O-11773174, O.C.S. Staff, Fort Sill, Okla.)	Lt.	U. S. Army
Downing, Roswell B.	25 S. Front St., Harrisburg, Pa. (A.A.F.I.S., Harrisburg, Pa.)	Lt.	Army Air Force
Dudley, Paul H.	109 San Antonio Dr., Long Beach, Calif. (Quantico, Va.)		Marine Corps
Dunlap, George Elmer	1636 S. Florence Pl., Tulsa, Okla. (N.T.S., Univ. of Ariz., Tucson, Ariz.)	Ens.	U. S. Navy
Dunn, David Arthur	Box 202, Tech. Sta., Lubbock, Tex. (O-432821, R.A.-A.F., Box 333, Roswell, N. Mex.)	Lt.	Army Air Force
Durgan, Herbert Leonard	Sun Oil Co., Beaumont, Tex. (A.P.O. 258, Camp Polk, La.)	Lt.	Field Artillery
Earle, Francis, Jr.	413 Draper Dr., Oakdale Farms, Norfolk, Va. (Amphibious Force, Adm. Cmd. N.O.B., Norfolk, Va.)		U. S. Navy
Eaton, J. Edmund	2062 N. Syramore Ave., Los Angeles, Calif. (A.P.O. 525, c/o P.M., New York, N.Y.)	Major	Army Air Force
Eberhardt, Adolph T.	Shell Oil Co., Inc., Box 426, Evansville, Ind. (Public Relations Office, Robins Field, Ga., O-285233)	Capt.	Army Air Force
Edwards, Harold S.	612 S. Grand, Lyons, Kan. (c/o P.M., F.P.O., New York, N. Y.)	Ens.	U. S. Navy
Egan, John A.	Service Club, Sheppard Field, Tex.	Capt.	U. S. Army
Eifler, Gus K.	2809 N. Guadalupe, Austin, Tex. (A.A.F.B.S., M.A.-A.F., Midland, Tex.)	Lt.	Army Air Force
Elkins, Campbell Hill	1803 13th St., Lubbock, Tex. (Pampa Army Air Base, Pampa, Tex.)	Capt.	Army Air Force
Elliott, Andrew C.	Box 403, Pilot Point, Tex. (Co. M, 304th Inf., Fort George G. Meade, Ga.	Lt.	Infantry
Elliott, John E.	700 Mercantile Bank Bldg., Dallas, Tex. (Dallas Chemical Procurement Dist.)	Major	U. S. Army

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Ellis, John Reese	c/o Helena Agency, R.F.C., Helena, Mont. (Bachelor Officer Quarters, Navy Yard, Portsmouth, N. H.)	Ens.	U. S. Navy
Ellsworth, Elmer W.	201 Grand Theater Bldg., Centralia, Ill. (Hdqtrs., Arctic, Desert & Tropic Information Center, A.A.F.-P.G.C., Eglin Field, Fla.)	Capt.	Army Air Force
Emery, Kenneth Orris	Navy Radio & Sound Lab., San Diego, Calif. (2649A)		U. S. Navy
Emmerich, Harry H.	4306 Twelfth St., N.E., Washington, D. C. (48th Troop Carrier Sqn., A.A.B., Maxton, N. C.)	Lt.	Army Air Force
Engel, Noel W.	122 Sherman Ave., Hamilton, Ohio (F.P.O., New York, N. Y.)	Lt.	U. S. Navy
Ervin, Lynn Delbert	Rt. 2, Box 70, Glenwood Springs, Colo. (c/o F.P.O., San Francisco, Calif.)	Capt.	Marines Corps
Esunas, Bernard Joseph	1110 Tower Petr. Bldg., Dallas, Tex. (Hendricks Field, Sebring, Fla.)	Capt.	Army Air Force
Evans, David Morgan	2213 24th St., Lubbock, Tex. (c/o F.P.O., San Francisco, Calif.)	Ens.	U. S. Navy
Evans, Frank G.	Photographic Interpretation School, U.S.N.A.S., Anacostia, D. C.	Lt.	U. S. Navy
Eyssell, Alfred R.	2151 Mulberry, San Antonio, Tex. (Btry D., 35th C.A.-T.B., Camp Wallace, Tex.)		Coast Artillery
Farish, Linn M.	Apt. 126, 3546 74th St., Jackson Heights, Long Is., N.Y.	Capt.	British Army
Farrand, Wm. Gardner	Sun Oil Co., Old Natl. Bank Bldg., Evansville, Ind. (A.P.O. 512, New York, N. Y.)		Corps. of Eng.
Feray, Dan E.	2110 Long, Beaumont, Tex. (6th Photographic (Compilation) Sqn., Peterson Field, Colorado Springs, Colo.)	Lt.	Army Air Force
Ferebee, D. M.	400 S. Seventh St., Mt. Vernon, Ill.		U. S. Navy
Ferguson, John Inger	2821 Oak St., Paso Robles, Calif. (826th T.D. Bn. (H), E. Garrison, Camp Roberts, Calif.)	Capt.	U. S. Army
Ferrell, Max Everett	Mountain View, Mo. (Academic Dept., Inf. School, Fort Benning, Ga.)	Capt.	Infantry
Fischer, Victor N.	614 Ockley Dr., Shreveport 63, La. (Plat. 5, N.T.S. (1), U. S. Naval Sta., Quonset Point, R. I.)	Lt.	U. S. Navy
Fisher, Theodore Glen	508 W. 7th St., Newkirk, Okla. (213,163, Office of Asst. Ind. Mgr., U.S.N. Ferry Bldg., San Francisco, Calif.)	Lt.	U. S. Navy
Fisher, Dunbar A.	1301 Austin Ave., Brownwood, Tex. (N.T.S., Ward Is., Corpus Christi, Tex.)	Lt.	U. S. Navy
Fitts, L. E., Jr.	Sinclair Prairie Oil Co., Box 521, Tulsa, Okla.		U. S. Army
Flesh, David James	515 Sherwood Dr., Shreveport, La.		U. S. Army
Flude, John W.	Independent Expl. Co., 901 Esperson Bldg., Houston, Tex. (275762 Deperming Station, Naval Supply Depot and Drydock, Bayonne, N. J.)	Lt.	U. S. Navy
Forrest, Lesh	1655 G St., Bakersfield, Calif. (A.P.O. 183, c/o Postmaster, Los Angeles, Calif.)	Pvt.	Corps of Eng.
Foster, Alden W.	2247 Oliver Bldg., Pittsburgh, Pa. (A.P.O. 603, Miami, Fla.)	Major	Army Air Force
Fouts, John M., Jr.	123 N. Rosemont, Dallas, Tex. (Harvard Univ. Dorm., Cambridge, Mass.)	Ens.	U. S. Navy
Fowler, Henry Florey	Box 215, Mt. Pleasant, Tex. (208003, E(V)S, Crew No. 3209, U. S. Navy Amphibious Tng. Base, Solomons Branch, Washington, D. C.)	Ens.	U. S. Navy
Franklin Donald Wilbert	The Ohio Oil Co., Bloomington, Ind. (302nd C.A. Bar. Bln. Bn., Camp Tyson, Tenn.)	Lt.	Coast Artillery
Frederickson, Edward A.	1105 Rutledge St., Madison, Wis. (O-913397, Dir. of Ground School, Big Spring Bombardier School, Big Spring, Tex.)	Lt.	Army Air Force
Fryou, Joe A.	Box 1268, Bay City, Tex. (17th Anti-Submarine Sqn., Boco Chica Air Base, Key West, Fla.)	Lt.	Army Air Force
Gahring, William Ross	Box 520, Shawnee, Okla. (Fort Sill, Okla.)	Major	U. S. Army
Galbreath, Glenn G.	2808 S. Cincinnati, Tulsa, Okla. (Army Air Base, Scribner, Neb.)	Lt.	Army Air Force
Galeski, Robert Benj.	5229 Eagle Rock Blvd., Los Angeles, Calif. (Cornell University, Ithaca, N. Y.)	Ens.	U. S. Navy

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Gardett, Peter H.	Box 542, Bakersfield, Calif. (N.T.S. (I) Quonset Pt., R. I.)	Ens.	U. S. Navy
Gardner, Edgar J.	1104 Woodland, Fort Worth 4, Texas.		Army Air Force
Gardner, Frank Johnson	Rinehart Oil News Co., Houston, Tex. (P.M.E. School, Class LI-2, Ft. Custer, Mich.)	Lt.	U. S. Army
Gardner, Jack Winston	341 N. Clifton, Wichita, Kan. (Naval Air Station, Photo. School, Bldg. 18, Pensacola, Fla.)	Ens.	U. S. Navy
Garrett, Julius Benj., Jr.	3615 Del Monte, Houston 6, Tex. (North Africa)	Lt.	Infantry
George, Robert Freeman	705 Union Natl. Bank Bldg., Wichita, Kan. (The Aloe Army Air Field, Victoria, Tex.)	Lt.	Army Air Force
Germond, Kenneth W.	c/o R. G. Atwood, Box 577, Sourlake, Tex. (c/o Fleet P.O.. San Francisco, Calif.)	Ens.	U. S. Navy
Geyer, Richard A.	(Magnetic Rangers, Naval Operating Base, Newport, R. I.)		U. S. Navy
Gibson, Donald Thomas	2008 Twenty-sixth St., Lubbock, Tex. 38066687, 5th Statistical Control Unit, Randolph Field, Tex.)	Cpl.	Army Air Force
Girdler, Tom Mercer, Jr.	13851 Clifton Ave., Lakewood, Ohio (Ordnance Dept. Cleveland Ord. Dist.)	Capt.	Ordnance Corps
Gisburne, John R.	5 Eddie St., Quincy, Mass. (Armed Guard Center, New Orleans, La.)	Ens.	U. S. Navy
Given, Robert Jennings	3708 E. Douglas, Wichita, Kan. (A.P.O. 525, New York, N. Y.)	Capt.	Army Air Force
Golden, John Muro	Elflex Co., 1706 Niels Esperson Bldg., Houston, Tex. (216 Armed Engr. B., Camp Chaffee, Ark.)	Capt.	Corps of Eng.
Goldsmith, Leo Jean	734 Humboldt St., Denver, Colo. (A.P.O. 3383, c/o Postmaster, San Francisco, Calif.)	Sgt.	Corps of Eng.
Goldstein, August, Jr.	935 Thora Blvd., Shreveport, La. (Lowry Field, Denver, Colo.)	Lt.	Army Air Force
Goodman, Herbert M.	c/o Frank L. Goodman, Coin, Iowa (T.D. 4, 533rd E.S.R. Eng. Amphibian Command, Camp Edwards, Mass.)		Tank Destroyer Bn.
Goodrich, Paul K.	Box 1139, Houston, Tex. (403rd F.A. Group, Camp Butner, N. C.)	Major	Field Artillery
Goudy, Lewis Willard	936 W. Elm, Yukon, Okla.	App. Seaman	U. S. Navy
Graham, Gordon Lloyd	c/o DeGolyer, MacNaughton & McGee, Continental Bldg., Dallas, Tex. (18039739, Hq. & Hq. Sqn., Second Air Force, Colorado Springs, Colo.)	Sgt.	Army Air Force
Gray, Roe Austin	1833 Grenshaw Blvd., Los Angeles, Calif. (Hq. E.U.T.C. s-3, Camp Claiborne, La.)	Lt.	Corps of Eng.
Green, Charles Frederic	1958 Ballejo St., San Francisco, Calif. (F.A.)	Lt.	Field Artillery
Greenham, Roy Leonard	Anglo-Iranian Oil Co., C/-C.O.R., Ltd., 90 William St. Melbourne, Australia		R. A. Air Force
Gregory, J. N.	Box 243, San Angelo, Tex. (Army Advanced Flying Field, San Angelo, Tex.)	Lt.	Army Air Force
Grossman, William L.	c/o Mrs. Wm. L. Grossman, Andover, N. Y.		U. S. Army
Guffey, Vernon E.	W. C. McBride, Inc., Tulsa, Okla. (D-V(S), Navy No. 293621, Naval Tng. Sta., Harvard Univ., Cambridge, Mass.)	Ens.	U. S. N. R.
Guntz, Henry A.	TS, A.A.F.T.T.C., Yale Univ., New Haven, Conn.	Cadet	Army Air Force
Guthrie, Robert Keith	551 Federal Bldg., Dallas, Tex. (U. S. Navy Res. at M. I. T.)	Ens.	U. S. N. R.
Gutru, Robert James	c/o George H. Gutru, Newman Grove, Neb.	Lt.	U. S. Navy
Gwinn, J. William	1326 B St., San Diego, Calif.	Yeoman 1st Class	U. S. Navy
Haenke, Martyn C.	885 S. Lucerne Blvd., Los Angeles, Calif. (3933 Haines Rd., St. Petersburg, Fla.)	Capt.	Army Air Force
Hagen, Cecil Vernon	"El Ranchito," Gonzales, Tex. (Naval Air Sta., Dallas, Tex.)	Lt.	U. S. Navy
Hake, Benjamin Franklin	561 E. 37th St., Indianapolis, Ind. (A.P.O. 722, c/o Postmaster, Seattle, Wash.)	Major	Corps of Eng.
Halbouty, M. T.	5 W. Lane, Houston, Tex. (O.Q.M.G., Fuels & Lubricants Div., Requirements Branch, Washington, D.C.)	Major	U. S. Army

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Hamilton, Edward A.	Shell Oil Co., Inc., Box 2099, Houston, Texas (8th F.A. Obsn. Bn., Camp Blanding, Fla.)	Lt.	Field Artillery
Hampton, James D.	McKaskill, Ariz. (B.A.A. Flt. E., Blytheville, Ark.)	Lt.	Army Air Force
Hancock, Bob	Box 87, Yale, Okla. (Ordnance Dept., Terminal 4, Portland, Ore.)	Major	Ordnance
Hanes, Vincent Eugene	706 W. Wash., Urbana, Ill., or 900 S. 12th St., Mt. Vernon, Ill. (U. S. NRAB, Block "H," Glenview, Ill.)	Cadet	U. S. N. R.
Hansen, Malcolm B.	Phillips Petr. Co., Esperson Bldg., Houston, Tex. (43-K, Sqn. "C," Ranking Aeronautical Academy, Tulare, Calif.)	Avn. Cadet	Army Air Force
Harang, Jack Francis	3008 Perkins Road, Baton Rouge, La. (N.T.S., Univ. of Ariz., Tucson, Ariz.)	Ens.	U. S. Navy
Harbison, Robert R.	1828 Harvard, Wichita, Kan. (Parris Island, S. C.)		Marine Corps.
Haring, Louis H., Jr.	1106 McCullough Ave., San Antonio, Tex. (Staff Officer, 61st F. A. Bn., Ft. Bliss, Tex.)	Lt.	Army Air Force
Harrison, John W.	1104 First Natl. Bank Bldg., Denver, Colo. (A.P.O. 473, c/o Postmaster, Seattle, Wash.)	Lt.	U. S. Army
Hart, Raymond M.	111 N. E. 23rd St., Oklahoma City, Okla. (78th Bn., Camp Roberts, Calif.)	Lt.	U. S. Army
Hatheway, Joseph G.	1245 Glendon Ave., Los Angeles, Calif.	Cadet	Army Air Force
Hauptman, H. R., Jr.	1204 W. 34th St., Austin, Tex. (Hdqtrs., 289th F.A. Bn., Camp Swift, Tex.)	Lt.	Field Artillery
Hawes, Julian	Stilwell, Okla. (AV(S), Navy 192800, Rm. 270, Hydrographic Office, Wash., D. C.)	Ens.	U. S. Navy
Hawkins, Glenn D.	2756 E. 25th St., Tulsa, Okla. (A.P.O. 453, c/o Postmaster, San Francisco, Calif.)	Lt.	U. S. Navy
Hawkins, Harold H.	1011 Cleveland Ave., Kansas City, Kan.		
Hawley, Luther David	100 Pelham Rd., New Rochelle, N. Y. (U.S.N.T.S., Avn. Maintenance, Norman, Okla.)	Ens.	U. S. Navy
Heap, George E.	Farmersburg, Ind. (Weather Observers School, 8th Tech. School Sqn. (Sp), T-316 Army Air Forces, Chanute Field, Ill.)		Army Air Force
Heck, Edward T.	West Va. Geol. Survey, Box 879, Morgantown, W. Va. (Fort Schuyler, N. Y.)	Lt.	U. S. Navy
Heid, Gordon W.	(O-924965, A.D.T.I.C., Eglin Field, Fla.)	Capt.	Army Air Force
Helis, James	105 Bennett Ave., New York, N. Y. (Automotive Sect., Ordnance Repl. Tng. Center, Aberdeen Proving Ground, Aberdeen, Md.)	Lt.	Ordnance Corps
Helmig, Phil D., Jr.	306 N. Lea Ave., Roswell, N. Mex. (A.P.O. 442, c/o P. M., San Francisco, Calif.)	Capt.	Army Air Force
Herd, John Harvey	Post, Texas (Sqn. M, Group Z, A.A.F.T.C., Yale University, New Haven, Conn.)	Cadet	Army Air Force
Hérold, John Sublett	Forest Development Co., Midland, Tex. (c/o Postmaster, New York, N. Y.)	Lt.	U. S. Navy
Hill, Orval Hall	1335 E. 26th Pl., Tulsa, Okla. (U. S. Air Service Cmd., U. Nations Depot 9, Norfolk, Va.)	Lt.	Army Air Force
Hiller, Carl Frederic	411 E. Belle, Rantoul, Ill. (A.A.F.T.T.S., Chanute Field, Ill.)		Army Air Force
Hinson, Hillord	1228 Sycamore, Lawton, Okla. (Co. A, Reception Center, Fort Sill, Okla.)	Capt.	Field Artillery
Hoffer, Clarence W.	532 20th St., N. W., Washington, D. C. (Room 4814, Navy Dept., Washington, D. C.)	Lt. Com.	U. S. Navy
Hopkins, Richard Holmes	Box 2038, Pittsburgh, Pa. (A.P.O. 626, New York, N. Y.)	Lt.	Corps of Eng.
Hopper, Richard H.	7958 W. Norton Ave., Los Angeles, Calif. (Army P.O. 501, San Francisco, Calif.)	Capt.	U. S. Army
Hornkohl, Frank E.	Box 1673, Bakersfield, Calif. (Enid, Okla.)	Capt.	Army Air Force
Hotchkiss, Henry	Middleton Farms, Vineyard Haven, R.F.D., Mass. (c/o Mail & Dispatch Sect. O.N.I., Navy Dept., Washington, D. C.)	Lt.	U. S. Navy
Howard, Douglas D.	Penrod Drilling Co., Box 328, Good Pine, La. (957 Engr. Topo. Co., Will Rogers Field, Okla. City, Okla.)	Sgt.	Army Air Force

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Howard, Edward L.	Howard Petr. Corp., 610 Citizens Natl. Bank Bldg., Tyler, Tex. (New Orleans, La.)	Lt.	U. S. Navy
Hubman, Carl W.	Box 122, Boulder, Colo. (Hdqtrs. Co., 4th E.A.U.T.C., March Field, Calif.)	Pvt.	Army Air Force
Hubman, Ralph Gordon	115 Key Ave., Wheeling, W. Va. (U. S. Naval Air Navigation School, Hollywood Beach Hotel, Hollywood, Fla.)	Ens.	U. S. Navy
Hudson, William A.	1810 Electric Bldg., Fort Worth, Tex. (O-500741, Ferry Command, 2nd Ferrying Sqn., 5th Ferrying Grp., Fairfax Airport, Kansas City, Kan.)	Lt.	Ferry Command
Huffmyer, Jack Roach	3516 Carnegie, Houston, Tex. (18118642, 21st T.S.S., Lowry Field 2, Colo.)	Pfc.	Army Air Force
Hunter, Harry M.	1419 Ninth St., W. Calgary, Alta., Canada (R. C. Engrs.)	Lt.	R. C. Eng.
Huntley, Louis Guy	Victoria Road, Donna, Tex. (c/o Naval Aerial Navigation Sch., Coral Gables, Fla.)	Ens.	Navy Air Force
Hurry, Floyd Phillip	1119 N. W. 37th St., Oklahoma City, Okla. (Quantico, Va.)	Lt.	U. S. Navy
Hussey, Keith Morgan	Dept. of Geol., Univ. of Houston, Houston, Tex. (A.A.F.B.S., Childress, Tex.)	Lt.	Army Air Force
Irwin, Carl B.	528 Adams Bldg., Port Arthur, Tex. (Resident Insp. of Naval Material, 836 New York Life Bldg., Kansas City 6, Mo.)	Ens.	U. S. Navy
Jackson, James Roy, Jr.	Montgomery, Tex. (5th C. A., Ventura, Calif.)	Lt.	Coast Artillery
Jacques, Arthur N.	(A.S.N. 17099197, Class 44-D, Sqn. 15, A.A.F.P.S. (Basic) C.A.A.F.; Chico, Calif.)	Avn. Cadet	Army Air Force
Jager, Eric Howard	235 N. Belmont, Wichita, Kan. (Co. B, Student Officers Tng. Regt., Tank Destroyer School, Camp Hood, Tex.)	Lt.	Tank Destroyer Bn.
James, Wright E.	2 Sunset Terrace, Eau Gallie, Fla. (Avn. Intelligence Officer, Naval Air Station, Melbourne, Fla.)	Lt.	U. S. Navy
Jenkins, George Marvin	419 Magazine St., Tupelo, Miss.		U. S. Army
Jenkins, Philip	c/o Mrs. Oliver Jenkins, Paintsville, Ky. (c/o Fleet P. M., San Francisco, Calif.)	Ens.	U. S. Navy
Johnson, Edward L.	1829 W. Summit, San Antonio, Tex. (351st Sq., 100th B. G. (H.), A.A.B., Sioux City, Iowa)	Capt.	Army Air Force
Johnson, Edward W.	3186 18th St. N., Arlington, Va. (Signal Corps., Engr. & Tech. Service, Office of the Chief Signal Officer, Washington 25, D. C. (Rm. 3B323, Pentagon Bldg.)	Capt.	Signal Corps
Johnston, John C.	c/o J. E. Rogers, Stanolind Oil & Gas Co., Box 591, Tulsa, Okla. (B.O.Q., Sub Chaser Tng. Center, Miami, Fla.)	Ens.	U. S. Navy
Jones, Charles T.	924 S. Sixth, McAlester, Okla. (38th Engrs., A.P.O. 622, c/o P.M., Miami, Fla.)	Lt. Col.	Corps of Eng.
Jones, Verner E.	1506 S. Race St., Urbana, Ill. (15th Air Depot Grp., Duncan Field, Tex.)	Lt.	Army Air Force
Jones, Walter B.	Dept. of Conservation, Montgomery, Ala. (Duncan Field, San Antonio, Tex.)	Lt. Col.	Army Air Force
Jordan, J. B.	Box 192, Konawa, Okla. A.P.O. 913, c/o P.M., San Francisco, Calif.)	Pvt.	Corps of Eng.
Jorgensen, Jay A.	302 Holmsley St., Midland, Tex. (689 Santa Rosa, Berkeley 6, Calif.)	Lt.	U. S. Army
Joujon-Roche, Jean Ed.	512 Fontaine St., Alexandria, Va. (O-254508, Corps of Engr. School, Staff of the Commandant, Ft. Belvoir, Va.)	Major	Corps of Eng.
Kaiser, George B.	532 Twentieth St. N.W., Washington, D. C. (Hq., Army Air Forces)	Lt. Col.	Army Air Force
Kearny, Clinton C.	710 Grayson St., San Antonio, Tex. (A.S.N. O-360243, Air Navigation Tng. School, Mather Field, Calif.)	Lt.	Army Air Force
Kelley, Frederic Richard	General Delivery, Belvedere, Calif. (Moffett Field, Calif.)	Lt.	Army Air Force
Kennedy, Joseph B., Jr.	51 Loines Ave., Merrick, N. Y. (Hdqtrs, 8th N.D., New Orleans, La.)	Lt.	U. S. Navy
Kerr, James Lee	337 Eleanor, San Antonio, Tex. (Navy No. 199667, U. S. Army Air Corps Meteorology School, University of California, Los Angeles, Calif.)	Ens.	U. S. Navy

Name	*Last Home Address* (*Military Address*)	*Rank*	*Branch of Service*
Ketterer, Walter Philip	119 Baywood Ave., S. Hills Br., Pittsburgh, Pa. (A.P.O. 633, c/o Postmaster, New York, N. Y.)	Sgt.	Army Air Force
Kilbourne, Lewis Perkins	Wakefield, La. (Hq. Sqn., Marine Corp. Air Sta., Brownfield, Quantico, Va.)	Lt.	Marine Corps
Kinser, James Hanford	Box 1059, Eustis, Fla.	Lt.	U. S. Navy
Kirkpatrick, Darrel L.	208 Natoma Ave., Santa Barbara, Calif. (A.S.N. 39573360, Co. A, 30th Ord. Tng. Bn., Scu. 1948, Camp Santa Anita, Arcadia, Calif.)	Pfc.	Ordnance Corps
Kivi, Wilho John	Rt. 2, Box 30, Ash, N. C. (384th Engr. Bn., Fort Bragg, N. C.)	Lt.	Corps of Eng.
Knight, Wilbur Hall	310 S. 10th St., Laramie, Wyo. (Camp Wolters, Tex.)	Lt.	Infantry
Kotick, O. F.	Tide Water Assoc. Oil Co., Bin H, Oildale, Calif. (A.P.O. 887, c/o Postmaster, New York, N. Y.)	Lt. Col.	Infantry
Kotyza, Fred Frank	Box 532, Roswell, N. Mex. (A-V (S) U.S.N.R., Crete, Neb.)	Ens.	U.S.N.R.
Kreidler, William Lynn	Tide Water Assoc. Oil Co., Giddens-Lane Bldg., Shreveport, La.	Lt.	U. S. Navy
Krouskop, Norman W.	3303 Pershing St., San Bernardino, Calif.	Lt.	Army Air Force
Kyle, Jerry Robert	2910 W. St., S.E., Washington, D. C. (16th Photo Sqn., Bolling Field, D. C.)	Lt.	Army Air Force
Lafferty, Robert C., Jr.	Owens, Libbey-Owens, 4007 Staunton Ave., Charleston, W. Va. (210752 N.A.S., DeLand, Fla. Navigation, AV(S))	Lt.	U. S. Navy
Lake, James L., Jr.	Subterrex, 701 Waugh Dr., Houston, Tex. (Tank Destroyer Center, Camp Hood, Tex.)	Major	Tank Destroyer, Bn.
Langford, David K.	W. B. Omhundro, City Natl. Bank Bldg., Wichita Falls, Tex. (Hdq. Field Services, A.S.C., Patterson Field, Fairfield, Ohio)	Lt.	Army Air Force
Langham, Noel Thomas	Box 141, Mission, Tex. (A.P.O. 523, c/o Postmaster, New York, N. Y.)	Capt.	U. S. Army
LaTouche, John D.	Box 2831, Beaumont, Tex. (Base Post Office, Canadian Army Overseas)	Lt.	R. C. Eng.
Latta, Lee Allen	2414 N. Shartel, Oklahoma City, Okla.	Ens.	U. S. Navy
Leach, T. W.	Patterson Hotel, Bismarck, N. Dak. (Coast Artillery, Anti-Aircraft)	Capt.	Coast Artillery
Lee, Herbert V.	400 E. 29th St., Sioux Falls, S. Dak. (A.P.O. 9404, c/o Postmaster, New York, N. Y.)	Capt.	Army Air Force
Leonard, Clarence Ziegler	201 E. 18th St., Higginsville, Mo. (A.P.O. 1207, c/o P. M., New York, N. Y.)		U. S. Army
Lester, John Lawrence	Shell Oil Co., Inc., Box 476, Centralia, Ill. (350th F. A., Camp Livingston, La.)	Capt.	Field Artillery
Levy, David Jacob	2217 Huldy St., Houston, Tex. (405th Tech. Sch. Sqn., Scott Field, Ill.)	Lt.	Army Air Force
Lewis, William Dabney	1240 Arden Rd., Pasadena, Calif. (Naval Tng. Station, Tucson, Ariz.)	Ens.	U. S. Navy
Lillibridge, Fred Stead	Box 101, Cunningham, Kan. (640 Topo. Engrs., Camp McCoy, Wis.)		Corps of Eng.
Liming, John A.	Standard Oil Co. of Venezuela, Box 1329, Caracas, Venezuela (21st T. D. Group Hq., Camp Hood, Tex.)	Capt.	Tank Destroyer Bn.
Lindner, Joseph Leicht	822 Stanley Blvd., Ardmore, Okla. (U.S.A.A.F.T.T.C. Gaylord Hotel, Miami Beach, Fla.)		Army Air Force
Lindsay, Sidney Afton	124 Geneseo Rd., San Antonio, Tex. (Hq. 3rd Air Force Eng. Section, Tampa, Fla.)	Lt.	Corps of Eng.
Little, Sterling E.	Wm. Helis Oil Co., 912 Whitney Bldg., New Orleans, La. (Rm. 27, Bldg. 701, Naval Air Base, Jacksonville, Fla.)	Cadet	Navy Air Force
Lock, John A.	210 Farragut, Laredo, Tex. (U. S. Marines, San Diego, Calif.)		Marine Corps
Loeblich, Alfred R., Jr.	452 College Ave., Norman, Oklahoma (Hq. Btry., 932nd F. A. Bn., Camp Gruber, Okla.)	Lt.	Field Artillery
Lonsdale, John T.	Winfield, Iowa (Anti-aircraft Artillery, 79th CA (AA), Manchester, Conn.)	Lt. Col.	U. S. Army

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Loomis, Frederic Brewster	Box 1347, Shreveport, La. (U. S. Naval Air Station, Houma, La.)	Ens.	U. S. Navy
Loring, Ralph Crapo	703 Fourth Ave., Ashbury Park, N. J.		Signal Corps
Lott, Frederick S.	Naval Ordnance Lab., U. S. Navy Yard, Washington, D. C.)	Lt. Com.	U. S. Navy
Lucke, John B.	Univ. of Conn., Storrs, Conn. (Hdqtrs. of Eastern Sea Frontier, New York, N. Y.)	Lt.	U. S. Navy
Lueth, Clinton A.	423 University Ave., San Antonio 1, Tex. (c/o F.P.O., San Francisco, Calif.)		U. S. Navy
Lugn, Alvin L.	1420 Jones St., San Francisco, Calif. (Univ. of Nebraska, Lincoln, Neb.)		
Lyle, W. E., Jr.	1611 Ninth St., Lubbock, Tex. (A.P.O. 675, c/o P.M., Miami, Fla.)		Corps of Eng.
Madden, Lloyd Willis	Box 326, Bucklin, Kan.		U. S. Army
Mahoney, Roger S.	Strafford, Pa. (Engr. Co., Engr. Bn. T. C., Camp Le Jeune, New River, N. C.)	Sgt.	Marine Corps
Mallory, Robert William	Stanolind Oil & Gas Co., Box 40, Casper, Wyo. (Dist. Coast Guard Officer, Ketchikan, Alaska)	Ens.	Coast Guard
Mankin, Warren Ward	2613 Lawrence Rd., Wichita Falls, Tex. (A.P.O. 560, c/o Postmaster, New York, N. Y.)	Capt.	Army Air Force
Manthos, Atlee G.	521 McLeary St., San Antonio, Tex. (Basic Flying School, Waco, Tex.)	Capt.	Army Air Force
Maravich, Milan D.	615 N. Kickapoo, Shawnee, Okla. (Co. G, 2nd Tng. Bn. Camp Ritchie, Md.)	Pvt.	U. S. Army
Martin, Bethea A.	1089 Cottonwood, Beaumont, Tex. (38418038, Co. E-41, 4th Plt., O.C.R., Ft. Belvoir, Va.)	Lt.	Corps of Eng.
Mathes, Donald E.	Republic Prod. Co., 1816 Petroleum Bldg., Houston, Tex. (742nd Tank Bn. (L), Camp Young, Indio, Calif.)	Major	Tank Bn.
Mathews, John William	Western Geophysical Co., Bakersfield, Calif.	Capt.	Corps. of Eng.
Matson, Thomas E.	1534 E. Seventeenth Pl., Tulsa, Okla. (Base Weather Sta., Grand Island, Neb.)		Army Air Force
Matthews, Charles L.	817 N. A St., Wellington, Kan. (A.P.O. 763, c/o Postmaster, New York, N. Y.)	Lt.	Corps of Eng.
Mauck, Melvin Dwight	Rt. 3, Princeton, Ind. (A.P.O. 763, c/o Postmaster, New York, N. Y.)	Lt.	U. S. Army
Maxson, John H.	2903 Green St., Harrisburg, Pa. (Air Intelligence School, Harrisburg, Pa.)	Major	Air Intelligence
Maxwell, John Crawford	Dept. of Geol., Princeton Univ., Princeton, N. J. (Fort Schuyler, The Bronx, New York, N. Y.)	Ens.	U. S. Navy
Mayer, Maurice J., Jr.	1170 Park Blvd., Baton Rouge, La. (425th Signal Co. (AVA), c/o 4th Air Force, San Francisco, Calif.)	Pvt.	Signal Corps
Mayfield, Gid Calmese	c/oFikes & Mirchison, Dallas, Tex. (F.P.O., San Francisco, Calif.)	Ens.	U. S. Navy
Mayfield, William I.	906 Camden St., San Antonio, Tex. (U. S. Naval Armed Guard Center, New Orleans, La.)	Ens.	U. S. Navy
Mayfield, William W.	455 Grove Ave., Clarksburg, W. Va. (Foreign Service)		U. S. Navy
McAdams, Ronald Earl	Shell Oil Co., Inc., San Antonio, Tex. (362nd Infantry, Camp White, Ore.)	Lt.	Infantry
McClain, Forrest Milton	1227 N. Grand, Enid, Okla. (A.P.O. 260, Nashville, Tenn.)	Lt.	Field Artillery
McClure, Harold Y.	Gulf Oil Corp., Fort Worth, Tex.	Ens.	U. S. Navy
McClure, Perry S.	Rt. 1, Elizabethtown, Ky. (O-260273, Hq., 310 Sig. Opn. Bn., Camp Campbell, Ky.)	Capt.	Signal Corps
McCobb, Harry W.	c/o T. C. McCobb, 30 Rockefeller Plaza, New York, N. Y. (A.P.O. 887, New York, N. Y.)	Lt. Col.	U. S. Army
McCoy, George Young	Republic National Bank, Dallas, Tex. (458th Engr. Depot Co., Camp Butner, N. C.)	Capt.	Corps of Eng.
McCready, Harry J., Jr.	4923 Knox Court, Denver, Colo. (Room 527, 03 Hall Naval Tng. Sta., Princeton, N. J.)	Ens.	U. S. Navy
McCune, Paul	Burk Burnett Bldg., Fort Worth, Tex. (Tank Destroyer Bn., Camp Hood, Tex.)	Lt.	Tank Destroyer Bn.
McDowell, Alfred N.	3001 Wood St., Texarkana, Tex. (N.T.S., Bowdoin College, Brunswick, Me.)	Ens.	U. S. Navy

Name	*Last Home Address* (*Military Address*)	*Rank*	*Branch of Service*
McGhee, George C.	6305 Malvey, Fort Worth, Tex. (Fleet Air Detachment, Naval Air Station, Eagle Mt. Lake, Tex.)	Lt.	Navy Air Force
McGovney, Paul E.	Honolulu Oil Corp., 215 Market St., San Francisco 5, Calif. (Hq. Co., E.U.T.C., Camp Claiborne, La.)	Lt.	Corps of Eng.
McIntyre, George Tayloe	I.T.I.O. Co., Box 4577, Capitol Hill Sta., Oklahoma City, Okla. (D-V (P), Rm. 22, Hollis, Naval Tng. School, Harvard Univ., Cambridge, Mass.)	Lt.	U. S. Navy
McKay, Alexander Ewing	1809 W. Broadway, Enid, Okla. (O-250317, A.A.F.S.-A.T., Orlando, Fla.)	Capt.	Army Air Force
McLendon, Dan Harvey	c/o Mrs. D. H. McLendon, Rayne, La. (A.P.O. 922, c/o Postmaster, San Francisco, Calif.)	Lt.	Coast Artillery
McMorris, Wm. A., Jr.	1640 N. Cincinnati, Tulsa, Okla. (Hq. Sqn., Gravelly Point, D. C.)		Army Air Force
McMurtry, Wilbur Earl	Box 1936, Wichita, Kan. (A.P.O. 34, c/o Postmaster, New York, N. Y.)		Field Artillery
McNab, James	363 Italia St., Covina, Calif. (O-433043, 768 Bomb Sqn., Walker Army Air Field, Victoria, Kan.)	Capt.	Army Air Force
McNaughton, Duncan A.	Box 1300, Kelowna, B. C. (J25956, c/o Bank of Montreal, 9 Waterloo Pl., London, S. W. 1, England)	Pilot	R. C. Air Force
McNutt, Gordon Russell	915 W. Twenty-third St., Austin, Tex. (Liberal Army Air Field, Liberal, Kan.)	Lt.	Army Air Force
Mead, Roy Gibbons, Jr.	307 N. Allesandro St., Temple City, Calif. (Hq. Sqn., M.C.A.S., Marine Barracks, Quantico, Va.)	Lt.	Marine Corps
Melsheimer, Albert H.	P. O. Box 507, Vicksburg, Miss. (A.P.O. 4781, c/o Postmaster, New York, N. Y.)	Lt.	Army Air Force
Messman, Roger L.	212 W. Eleventh, Hays, Kan. (O-1546308, Sta. Hospital, Peterson Field, Colorado Springs, Colo.)	Sgt.	Medical Corps
Mestier, Arthur J., Jr.	Berwyn, Barbados, B.W.I. (2818 E. Menlo Blvd., Milwaukee11, Wis.)	Lt.	
Meyer, Ruskin H.	Rt. 2, Anthony, Kan. (A.P.O. 763, c/o Postmaster, New York, N. Y.)	Pvt.	Signal Corps
Michaelson, Louis Henry	251 N. Poplar, Wichita Kan. (26th Ferrying Sqn., Berry Field, Municipal Airport, Box 535, Memphis, Tenn.)	Lt.	Ferry Command
Michaux, Frank W., Jr.	3417 Ella Lee Lane, Houston, Tex. (Treasure Island, San Francisco, Calif.)	Lt.	U. S. Navy
Miles, Phil Middleton	Barrow Rd., Lexington, Ky. (A.P.O. 887, c/o Postmaster, New York, N. Y.)	Capt.	Corps of Eng.
Miller, Lloyd Eugene	4715 Pillsbury Ave. S., Minneapolis, Minn. (D-V (P), Newport, R. I.)	Ens.	U. S. Navy
Miller, Powell Wesley	Box 421, Merkel, Tex. (A.A.F.A.I.S., Harrisburg, Pa.)	Lt.	Army Air Force
Miller, Richard F.	1105 S. Fillmore St., Denver 10, Colo. (O-517516, Co. A, 1312th Engr. Regt. (G.S.), E.U.T.C., Camp Claiborne, La.)	Lt.	Corps of Eng.
Ming, Raymond E.	Stanolind Oil & Gas Co., Houston, Tex. (c/o Fleet P.O., San Francisco, Calif.)	Lt.	U. S. Navy
Mohler, Donald Phillips	Humble Oil & Refg. Co., Amarillo, Tex. (497th Engr., Heavy Shop Co., E.U.T.C., Camp Claiborne, La.)	Lt.	Corps of Eng.
Monahan, Charles J.	U. S. Engr. Office, Geology Subsection, Little Rock, Ark. (0-1102872, A.P.O. 860, c/o Postmaster, New York, N. Y.)	Lt.	Corps. of Eng.
Monsour, Edward	2754 Lakeshore Dr., Shreveport, La.	Ens.	U. S. Navy
Monsour, Emil	Sun Oil Co., Box 2880, Dallas, Tex. (57th A.A.F.F.-T.D., Ocala, Fla.)	Capt.	Army Air Force
Moody, John D.	635 Oneonta St., Shreveport, La.	Lt.	Marine Corps
Moore, Raymond C.	University of Kansas, Lawrence, Kan. (1342 Temp. G Bldg., 23rd St. N. W., Washington, D. C.)	Major	Corps of Eng.
Moorhead, Johnny Bob	1005 Eleventh St., Wichita Falls, Tex. (Fleet P.O., San Francisco, Calif.)	Ens.	U. S. Navy
Moresi, Cyril K.	3304 Tampa St., Houston 4, Tex. (Belle Isle Court Apt. 67, 31 Venetian Way, Miami Beach, Fla.)		U. S. Navy
Morgan, Charles Gill	Apt. 196, Arlington Village, Arlington, Va. (A.P.O. 638, c/o Postmaster, New York, N. Y.)	Lt. Col.	Army Air Force
Mullinax, Jack D.	Rt. 3, Chesnee, S. C. (1st E. S. R., Fort Belvoir, Va.)	Lt.	Corps of Eng.
Mueller, Frederick W.	Skelly Oil Co., 1305 Esperson Bldg., Houston 2, Tex.		U. S. Army

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Munoz, Robert R.	1033 Securities & Exchange Bldg., 18th & Pennsylvania Aves., Washington, D. C. (Military Intelligence Div.)	Lt.	Military
Myers, Clay Kenton	c/o John S. Myers Co., Albany, N. Y. (Code 352, Bur. of Ships, Navy Dept., Washington, D. C.) (Temp. Duty, Miami, Fla.)	Ens.	U. S. Navy
Nance, James W.	608 N. Hudson, Altus, Okla. (Hydrographic Office, Air Navigation Div., Rm. 270, Washington, D. C.)	Lt.	U. S. Navy
Neely, Joseph	Lovell, Wyo. (Co. I, 159th Inf., A.P.O. 7, San Francisco, Calif.)	Lt.	Infantry
Neiler, William Dixon	212 N. Thirtieth St., Billings, Mont. (O–1105057, 169th Engr. Bn., Camp Beale, Calif.)	Lt.	Corps of Eng.
Nelson, Jean O.	2101 W. Summit, San Antonio, Tex. (Camp Claiborne, La.)	Capt.	Corps of Eng.
Nelson, Raymond T.	c/o Charles Hebert, White Castle, La. (Anti-aircraft Rep.Tng. Center, Camp Wallace, Tex.)	Lt.	U. S. Army
Newell, Donald Frost	400 W. Washington, Blair, Neb. (61st F. A. Bn., Ft. Bliss, Tex.)	Capt.	Field Artillery
Newell, Harlan Willard	2692 London Rd., Cleveland, Ohio		U. S. Army
Newhouse, Lester	(A.P.O. 867, c/o Postmaster, New York, N. Y.)		
Nicholls, William M.	134 W. Craig Pl., San Antonio, Tex. (A.P.O. 627, c/o Postmaster, New York, N. Y.)	Capt.	Army Air Force
Niven, Robert N.	Box 1096, Alexandria, Va.	Lt.	Army Air Force
Noland, Orval W.	c/o W. A. Noland, Waukomis, Okla. (A.P.O. 1069, New York, N. Y.)	Lt.	Army Air Force
Noll, Donald E.	701 Woodland Ave., Springfield, Ill. (1st Bn., 14th Marines, Camp Pendleton, Calif.)	Capt.	Marine Corps
O'Brien, Joseph Alfred	2910 Jackson, Sioux City, Iowa (174945, Gunnery School, Pensacola, Fla.) (N.A.S.)	Ens.	U. S. Navy
O'Flynn, James Baldwin	Richfield Oil Corp., Bakersfield, Calif.		U. S. Army
Oliver, Richard R.	211 Ballston Ave., Scotia, N. Y. (456 Bomb. Sqn., MacDill Field, Tampa, Fla.)	Lt.	Army Air Force
Olson, Odell Cecil	Box 349, Brady, Tex.	Lt.	Marine Corps
Orman, Freeman L., Jr.	Box 374, Austin, Tex. (V-7 Indoctrination Course, Notre Dame University, Notre Dame, Ind.)	App. S.	U. S. Navy
Orr, Mark Lafon	Idalou, Tex. (VSB #4, Cecil Field, U.S.N.A.S., Jacksonville, Fla.)	Lt.	Naval Air Force
Owen, Edgar W.	532 Milam Bldg., San Antonio, Tex. (A.P.O. 925, c/o Postmaster, San Francisco, Calif.)	Major	Army Air Force
Paige, Sidney	Office of Div. Engr., N. Atlantic Div., 270 Broadway, New York, N. Y.		Corps of Eng.
Pakiser, Louis C., Jr.	480 S. Raleigh St., Denver, Colo. (37343719, H. & S. Co., 635th Engr. Topo. Bn., Camp Livingston, La.)	Pvt.	Corps of Eng.
Parhiala, Leimo I.	48 Euclid Ave., Quincy 69, Mass.		U. S. Navy
Park, Noel Robertson	338 N. Kings Rd., Los Angeles, Calif. (Hq. Co., 504th Signal Regt., Camp Haan, Calif.)	Pvt.	Signal Corps
Park, Stafford	4556 Graywood Ave., Long Beach, Calif. (c/o Postmaster, New York, N. Y.)	Lt.	U. S. Navy
Parker, Norbert A.	Rt. 2, Fort Wayne, Ind. (Merchant Marines, Sheepshead Bay, Long Island, N. Y.)		Merchant Marine
Parsons, Kenneth R.	7725 Blackstone Ave., Chicago, Ill. (A.P.O. 345, Camp Hale, Colo.)	Pvt.	Infantry
Paschall, Robert H.	Box 1300, Bakersfield, Calif. (P.I.U., U.S.N.A.S., Anacostia, D.C.)	Ens.	U. S. Navy
Patterson, Luther E., Jr.	1208 N. W. Thirty-sixth St., Oklahoma City, Okla. (Australia)	Major	Field Artillery
Payne, C. Winthrop	Carter Oil Co., Vicksburg, Miss. (F.P.O., San Francisco, Calif.)	Ens.	U. S. Navy
Payne, Max B	560 Haberfelde Bldg., Bakersfield, Calif. (AV(P), U.S.N.R., Naval Tng. School (Indoctrination), Hollywood Beach Hotel, Hollywood, Calif.)		U. S. Navy
Pearson, Raymond E.	265 Redondo Ave., Long Beach, Calif. (Randolph Field, Tex.)	Lt.	Army Air Force

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Pelto, Chester R.	Geol. Dept., Georgia School of Technology, Atlanta, Ga. (Straus C-22, NTS (Comm.), Harvard Univ., Cambridge, Mass.)	Ens.	U. S. Navy
Pence, Richard H.	3554 Carlin Ave., Lynwood, Calif. (Office Commandant Naval Operating Base, Pier A., Long Beach, Calif.)	Lt. Com.	U. S. Navy
Penn, William Y.	810 W. Storey, Midland, Tex. (Sqn. 15, Class 43-6, Abbey Hotel, Miami Beach, Fla.)	O.C.	Army Air Force
Pennel, Harry David	Box 3, Lafayette, La. (SCU 1928 Range Det., Camp Roberts, Calif.)	Lt.	Field Artillery
Pickrell, Daniel J.	321 Ramona Ave., El Cerrito, Calif.	Lt.	U. S. Navy
Pierce, Harold F.	1304 S. Indianapolis, Tulsa, Okla. (U.S.C.G.R., District Coast Guard Officer, 1st Naval District, Boston, Mass.)	Ens.	Coast Guard
Pinkley, George R.	818 W. Kings Highway, San Antonio, Tex.	Capt.	Chem. Warfare Corps
Pool, Frank Morrow	1403 Indiana Ave., Waco, Tex. (A.P.O. 251, c/o Postmaster, New York, N. Y.)		U. S. Army
Porter, Phil	Apt. B-11, John Adams Presidential Gardens, Alexandria, Va.	Ens.	U. S. Navy
Portis, Richard Wayne	Fairfax, Mo. (O.C.S., Class 51, Co. 3, Ft. Knox, Ky.)	O.C.	U. S. Army
Potsch, John Peter	1517 S. Fifty-first St., Cicero, Ill. (Fleet P.O., New York, N. Y.)	Lt.	U. S. Navy
Prescott, Gordon Walter	Halliburton Oil Well Cementing Co., Great Bend, Kan. (9th Detachment, Special Troops, 2nd Army, Fort Leonard Wood, Mo.)	Major	U. S. Army
Preston, John Basil	Glasgow, Ky. (Co. I, 2nd Engr. Sch. Regt., O.C.S., Ft. Belvoir, Va.)	O.C.	Corps of Eng.
Price, Paul H.	State Geological Survey, Morgantown, W. Va. (Special Reserve, A.M.G.S., Stanford University, Palo Alto, Calif.)	Major	U. S. Army
Punches, Richard Knapp	(A.P.O. 924, c/o Postmaster, San Francisco, Calif.)	Lt.	Corps of Eng.
Pyle, Howard C.	2745 29th St. N.W., Washington, D. C. (O-922191, Fuels & Lubricants Div., Office of Quartermaster General, Washington, D. C.)	Major	U. S. Army
Pyre, Augustin	Rt. 2, Madison, Wis. (36278474, Hq. 69th Recon. Grp., Ecles Field, La.)		Army Air Force
Quigley, Claude M., Jr.	Maysville, Mo.	Pvt.	Corps of Eng.
Rankin, Robert E.	910 W. Louisiana St., Midland, Tex. (470 Bomb Grp. Hdg., Mt. Home, Idaho)	Lt.	Army Air Force
Ray, W. C.	315 W. Twohig Ave., San Angelo, Tex. (Petroleum Distribution Unit, Camp Claiborne, La.)	Capt.	Corps of Eng.
Reavis, George David	622 N. Park, Shawnee, Okla. (Btry. F, 32nd Bn., 8th Regt., Field Artillery Repl. Tng. Center, Ft. Sill, Okla.)	Pvt.	Field Artillery
Reed, Charles Merton	229 Penhurst St., Rochester, N.Y. (Co. D, 29th E.R.T.C. Bn., 2nd Platoon, Ft. Leonard Wood, Mo.)	Pvt.	Corps of Eng.
Reeves, Frank W.	2905 Merida, Ft. Worth, Tex.	Capt.	Army Air Force
Reigle, Edward E.	613 W. Storey, Midland, Tex. (Flight Instructor, 723 Oak St., Denton, Tex.)		Army Air Force
Reiss, John Walter	1810 Santa Fe St., Corpus Christi, Tex.	Lt.	Army Air Force
Relf, George O., Jr.	El Mirasol Hotel, Santa Barbara, Calif. (40 Pinckney St., Boston, Mass.)	Ens.	U. S. Navy
Renfro, Harold Bell	c/o Mrs. H. B. Renfro, 1545 S. Yorktown, Tulsa, Okla. (179998)	Ens.	U. S. Navy
Renick, B. Coleman	219 Park Hill Dr., San Antonio, Tex. (Kelly Field, San Antonio, Tex.)	Lt. Col.	Army Air Corps
Revelle, Roger R. D.	9201 Flower Ave., Silver Spring, Md. (77919, Bureau of Ships, Navy Dept., Washington, D. C.)	Lt. Com.	U. S. Navy
Rhodes, Edward J.	Schenectady Q. M. Depot, Schenectady, N. Y.		U. S. Army

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Richards, Edward F.	1020 Burdette St., New Orleans, La.		U. S. Navy
Rife, Byron	523 Aztec Bldg., San Antonio, Tex. (#15 Staff Area, Kankakee Ordnance Works, Joliet, Ill.)	Lt. Col.	U. S. Army
Roark, Louis Claude	2652 S. Trenton, Tulsa, Okla. (A.P.O. 708, San Francisco, Calif.)	Lt.	Army Air Force
Robbins, Harold Weston	Soil Conservation Service, Torrington, Wyo. (Co. A, 29th. Engr. Bn., Eugene, Ore.)	Pvt.	Corps of Eng.
Roberts, Charles V., Jr.	1307 Broadway Blvd., Kilgore, Tex.		Army Air Force
Robichaux, Douglas B.	Box 207, Jeanerette, La. (A.P.O. 84, c/o Postmaster Shreveport, La.)	Major	Field Artillery
Robie, Robert Hodges	111 Purdue Union, W. Lafayette, Ind. (Naval Air Station, Dallas, Tex.)	Lt.	U. S. Navy
Robinson, Joseph	816 Sumner Ave., Springfield, Mass. (North Africa)		U. S. Army
Rodgers, John Albert	Box 206, Bryan, Tex. (c/o Fleet P.O., San Francisco, Calif.)	B's'n Mate	U. S. Navy
Rogatz, Henry	124 E. 84th St., New York, N. Y.	Lt.	Army Air Force
Rogers, Jess A.	Box 1221, Pampa, Tex.		U. S. Army
Rogers, Wilbur Frank	231 E. Seward, Seward, Neb. (c/o Postmaster, New York, N. Y.)		U. S. Navy
Roig, Chester A., Jr.	73 Carroll St., Poughkeepsie, N. Y. (N.T.S. (1), Naval Air Sta., Quonset Pt., R. I.)	Ens.	U. S. Navy
Ronbeck, Arthur Charles	Superior Oil Co., Houma, La. (Pensacola, Fla.)	Ens.	Naval Air Force
Roper, Frank C.	Roper & Todd, Esperson Bldg., Houston, Tex. (Box 422, Brooks Field, Tex.)	Lt.	Army Air Force
Ross, E. McIver, Jr.	2148 Addison Rd., Houston, Tex. (Warrant Officer, W-2130169 U.S.A.A.F., Ellington Field, Tex.)	Warrant Officer	Army Air Force
Rukas, Justin Matthew	1957 Wisteria St., Baton Rouge, La. (A.P.O. 930, c/o Postmaster, San Francisco, Calif.)		Infantry
Ruley, Eugene Evan	2610 Beech St., Parkersburg, W. Va. (Student Army Specialist Tng. Corps)	Pvt.	U. S. Army
Russell, Harry Jones, Jr.	Gulf Oil Corp., Wichita, Kan. (A.P.O. 634, c/o Postmaster, New York, N. Y.)	Lt.	Army Air Force
Ruwwe, John W.	Rm. 405, 777 Court Ave., Memphis, Tenn. (c/o Fleet P.O., San Francisco, Calif.)	Lt.	U. S. Navy
Ryan, Thomas Patrick	c/o P. J. Ryan, Box 1267, Ponca City, Okla. (A.P.O. 871, c/o Postmaster, New York, N. Y.)	Capt.	U. S. Army
Samuell, John Howard	409 S. Eddy St., Pecos, Texas (Pecos Basic Army Air Force Flying School, A.S.C. Post Engineers)	Capt.	Army Air Force
Sands, Charles Dudley	Ohio Oil Co., Box 253, Lafayette, La. (97th Engr. Bn., Eglin Field, Fla.)	Lt.	Corps of Eng.
Sappington, Chester	330 G, S.W., Ardmore, Okla. (Btry. D, 211th C.A. (AA), Crockett, Calif.)	Lt.	Coast Artillery
Sartain, Maxwell Roland	1415 N.W. 34th, Okla. City, Okla. (Air Intelligence School, Harrisburg, Pa.)	Lt.	Army Air Force
Saville, Wilson G.	1348 Esperson Bldg., Houston, Tex. (Galveston, Tex.)	Lt. Col.	Corps of Eng.
Schall, Fred Muller, Jr.	4834 St. Charles St., New Orleans, La. (Fleet Post Office, San Francisco, Calif.)	Lt.	Navy
Schenck, Hubert G.	Box 1528, Stanford Univ., Calif. (Fort Custer, Mich.) (O-523083)	Major	U. S. Army
Schneider, William T.	c/o R. M. Jones, Honolulu Oil Corp., Midland, Tex. (826 S. 10th St., Corvallis, Ore.) (O-344858)	Capt.	Corps of Eng.
Schweer, Henry F.	600 Eubanks, Oklahoma City, Okla. (Miami Beach, Fla.)	Capt.	Army
Seals, Wilburn Hall	Fleet P.O., San Francisco, Calif. (Mail Returned)	Lt.	Navy
Selover, Joseph Britton	10207 Lakeshore Blvd., Cleveland, Ohio (Naval Air Base, Quonset, R. I.)	Lt.	Naval Air Corps
Shaeffer, Stanley B.	1647 Davis Ave., Whiting, Ind.	Ens.	Navy
Sheller, James Warner	Box 455, Studio City Sta., N. Hollywood, Calif.	Lt.	Coast Artillery
Sherman, Wilbur Brown	679 High St., Orville, Calif. (46th Bombardment Wing, Army Air Base, Ardmore, Okla.)	Capt.	Army Air Force
Shoemaker, Richard W.	Ohio Oil Co., Box 193, Bakersfield, Calif.	Ens.	Navy

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Simmons, Rouse	535 Toyopa Dr., Pacific Palisades, Calif. (Western Procurement Dist., A.A.F., Material Command, 3636 Beverly Blvd., Los Angeles, Calif.)	Capt.	Army Air Force
Simon, Louis Joseph, Jr.	317 Pasqual Ave., San Gabriel, Calif. (O–330932) (Hdqtrs. Btry., 118th AAA Gun Bn. (Mbl), Camp Haan, Calif.)	Lt.	Army
Skinner, John Wesley	803 Cuthbert, Midland, Tex. (18078531, 766 T SS) (2nd Comp. Sqn. (Sp.) A.A.F., Marshall Field, Ft. Riley, Kan.)	Pfc.	Army Air Force
Smith, Fred E.	841 M. & M. Bldg., Houston, Tex. (Waco Army Flying School, Waco, Tex.)	Lt.	Army Air Force
Smith, Marcus A. J.	609 E. Clay, Mt. Pleasant, Iowa (Polloksville Field, New Bern, N. C.)	Lt.	Marine Corps
Smith, Ralph E.	2829 Cantey, Ft. Worth, Texas (20th Photo Sqn., Peterson Field, Colorado Springs, Colo.)	Lt.	Army Air Force
Snider, Lafayette B.	409 W. Lynwood, Apt. 2, San Antonio, Texas (South Pacific War Zone)	Capt.	Army Air Force
Snyder, Raymond W.	1649 Roslyn St., Denver, Colo. (756th Tech. School, Sqn. (SP), Buckley Field, Colo.)	Capt.	Army Air Force
Sparenberg, G. R.	Lane-Wells Co., Box 531, New Iberia, La.		Army
Speer, George Woodrow	202 S. Bleakley Dr., Wichita, Kan. (Liaison Pilot Detachment, W.A.F.S., Waco, Tex.)	Pvt.	Army Air Force
Spencer, Charles Grason	Rt. 5, Bloomington, Ind. (300th Engr. Bn., Camp White, Ore.)	Lt.	Corps of Eng.
Sprengling, Kurt	1407 Sutherland Pl., Birmingham, Ala. (Ordnance Works, Sylacauga, Ala.)	Lt.	
Stapp, Wilford Lee	Drilling & Expl. Co., Inc. Box 1575, Hobbs, N. Mex. (Office of Communications Officer, Army Air Force Flexible Gunnery School, Buckingham Army Air Field, Fort Myers, Fla.)	Lt.	Army Air Force
Stewart, Sam	825 S. LeDoux Rd., Los Angeles, Calif.	Lt.	Army Air Force
Stoker, Carl E.	Longton, Kan. (Naval Tng. Sta., Cornell Univ., Ithaca, N. Y.) (191198)	Lt. (j.g.)	Naval Air Force
Stolz, Harry P.	c/o Stanley & Stolz, 510 S. Spring St., Los Angeles, Calif. (Ass't Insp. Naval Petr. Reserves, 402 Federal Bldg., Los Angeles, Calif.)	Lt. Com.	Navy
Stone, George Bailey	5010 Caroline Blvd., Houston, Tex. (Naval Ordnance Lab., U. S. Navy Yard, Washington, D. C.)		Navy
Stone, Richard O'Neill	1420 S. Fifth St., Alhambra, Calif. (Kelly Field, San Antonio, Tex.)	Lt.	Army Air Force
Stone, Solon Wallingford	493 Walnut St., Meadville, Pa. (Fleet P.O., San Francisco, Calif.)	Ens.	Navy
Stotler, Raymond T., Jr.	Ambassador Hotel, 7 W. 14th, Tulsa, Okla. (First Processing Hq., Smoky Hill Army Air Field, Salina, Kan.)	Lt.	Army Air Force
Suffield, Harry Franklin	1911 S. Ninth, Woodward, Okla. (Hq., 102nd Inf. Div., G-2 Sect., Camp Maxey, Tex.)	Major	Army
Swesnik, Robert M.	1528 N. Western, Oklahoma City, Okla. (B Battery, 391st Armored Field Artillery Bn., 3rd Armored Div., Camp Polk, La.)	Lt.	Army
Swiger, Rual B.	Nixon Bldg., Corpus Christi, Tex. (South Pacific War Zone)	Capt.	Army Air Force
Taber, Edward C., Jr.	Shell Oil Co., Inc., Box 1191, Tulsa, Okla. (Military Intelligence, Camp Savage, Minn.)		
Tapp, Theodore L.	(C.E., Foreign Div., P.A.W., New Interior Bldg., Washington 25, D. C.)	Lt.	Corps of Eng.
Tapper, Wilfred	Halliburton Cementing Co., 2301 Magnolia Bldg., Dallas, Tex. (U.S.S. Y.M.S. 337, F.P.O., San Francisco, Calif.)	Ens.	Navy
Tarr, Russell S.	2244 S. Twenty-fifth Pl., Tulsa, Okla. (G-738, Gravelly Point, Washington, D. C.) (O-496065)	Capt.	Army Air Force
Taylor, M. Hall	701 S. Grand, Lyons, Kan. (A.P.O. 954, San Francisco, Calif.)	Capt.	Army

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Teel, Dick	327 Parland Pl., San Antonio, Tex. (11th Photo Mapping Sqn., Protu Army Air Base, Colorado Springs, Colo.)	Lt.	Army Air Force
Teichman, Joseph B.	210 Maple Ter., Dallas, Tex. (119th Obsn. Sqn., Ft. Dix, N. J.)	Lt.	Army Air Force
Tennis, Langdon Carlisle	Jacaranda Hotel, Avon Park, Fla. (Group Navigation Officer, 336th Bomb. Group, Lake Charles, La.)	Lt.	Army Air Force
Terrill, John V.	Box 1461, Midland, Tex. (Army-Navy Petr. Bd., Rm. 2830, Navy Bldg., Washington, D. C.)	Capt.	Army Air Force
Tester, Allen C.	228 Woolf Ave., Iowa City, Ia. (Overseas)	Capt.	Corps of Eng.
Thams, William Hoover	1311 Boston, Muskogee, Okla. (311 Field Artillery Bn., 79th Div., Camp Blanding, Fla.)	Lt.	Army
Thomas, Ralph Nelson	2625 Newman St., Ashland, Ky. (Office of the Quartermaster General, Washington, D. C.)	Lt.	Army
Thomas, William A.	509 S. College St., Mt. Pleasant, Mich. (Officers Class J.8 P.M.G.S., Bldg. 2302, Fort Custer, Mich.)	Major	U. S. Army
Thompson, James D.	509½ Polk St., Amarillo, Tex. (Naval Aviation Instr., Sq. 12-C, Cahaniss Field, U.S.N.A.T.C., Corpus Christi, Tex.)	Lt.	Navy Air Force
Thompson, Lester S.	223 Forest Rd., Douglaston, N. Y. (A.P.O. 523, c/o Postmaster, New York, N. Y.)	Major	Corps of Eng.
Thorup, Richard Russell	133 Willow St., Salinas, Calif. (Armed Guard Center (Pacific) Treasure Island, San Francisco, Calif.)		Navy
Thrasher, Glen Clair	The Texas Co., Box 2100, Denver, Colo., Co. D., 1st Bn., 382nd Inf., Camp Adair, Ore.	Lt.	Army
Tichy, James Robert	328 S. 17th St., Lincoln, Neb. (c/o Fleet P.O., San Francisco, Calif.)	Ens.	Navy
Tobin, Don Freeman	907 Milam Bldg., San Antonio, Tex.	Ens.	Navy
Todd, John David	c/o Roper & Todd, Esperson Bldg., Houston, Tex. (Army Air Base, Dodge City, Kan.)	Major	Army Air Corps
Tollefson, Everett H.	332 Buckhannon Ave., Clarksburg, W. Va. (No. 230125, Bureau of Aeronautics, Navy Dept., Washington, D. C.)	Lt.	Navy
Tompkins, Joseph D.	Dallas Athletic Club, Dallas, Tex. (Miami Springs Battle Creek Hotel, Miami Springs, Fla.)	Major	Army Air Force
Travis, Russell B.	Forestville Calif. (23055, NT(I) Ft. Schuyler, New York 61, N. Y.)	Ens.	U. S. Navy
Tuck, Louis Lester	2201 Broadway, Mt. Vernon, Ill. (Sqn. 15A, Naval Air Station, Kingsville, Tex.)	Ens.	Navy
Tucker, Reagan	521 Naples St., Corpus Christi, Tex. (Co. D, 36-2, 2nd Eng. School Regt., Fort Belvoir, Va.)		Corps of Eng.
Tucker, Rietz C.	Box 265, Morgantown, W. Va. (Hq. 336th Bombardment Grp., Avon Park, Bombing Range, Avon Park, Fla.)	Lt.	Army Air Corps
Turner, George R.	2301 N.W. 30th, Okla. City, Okla. (C.A.C., Btry C, 29th Bn., Camp Wallace, Tex.)	Lt.	Coast Artillery
Turner, Johnathan D.	Box 1, Kearney, Neb. (Local Defense School, Treasure Island, San Francisco, Calif.)	Ens.	Navy
Uhrig, Leonard F.	Shell Oil Co., Inc., Box 2099, Houston, Tex. (Maint. Bn. 5th A.D., C.A.T.S., Northwestern Univ., 357 E. Chicago Ave., Chicago, Ill.)	Major	Coast Artillery
Uri, Joseph John	512 N. Okmulgee, Okmulgee, Okla. (Fleet P.O., San Francisco, Calif.)	Lt.	Navy
Ustynik, Edwin F.	Box 90, Rosenberg, Tex. (1525 Service Unit, Co. C, Rm. 268, Phoenix Hotel, Lexington, Ky.)	Cpl.	Army
Vandenberg, F. E.	c/o Mrs. R. W. Heffelfinger, 2318 W. 8th St., Los Angeles, Calif.	Lt.	Navy
Van Eaton, Raymond A.	Mills Bennett Prod. Co. (A.P.O. 938, Postmaster, San Francisco, Calif.)	Lt.	Army
Verckler, Stewart P.	Box 532, Abilene, Tex. (30th Engr. Topo. Bn. (GHQ), Co. B, Ft. Belvoir, Va.) (37243498)	Cpl.	Corps of Eng.
Veseley, Leon Robert	1711 5th Ave., S.E., Cedar Rapids, Ia. (St. Louis Ordnance Plant, St. Louis, Mo.) (O-283528)	Capt.	

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Vincent, Mordelo L., Jr.	Box 103, Lake Charles, La. (A.P.O. 420, c/o Postmaster, New York, N. Y.)	Capt.	Army Air Force
Wadsack, George E., Jr.	1517 Oklahoma Ave., Norman, Okla. (A.P.O. 675, Miami, Fla.)	Lt.	Army Air Force
Wadsworth, A. H., Jr.	2000 Austin St., Bay City, Tex. (U. S. Engrs., 506 Federal Bldg., Salt Lake City, Utah)		Corps of Eng.
Waggoner, Stephen Gose	1600 Buchanan St., Wichita Falls, Tex. (Asst. Dir. of Personnel, Civilian Personnel Officer, Fort Huachuca, Ariz.)	Lt.	Army
Wahlstrom, Edwin A.	1700 W. Holloway, Midland, Tex. (Insp. Naval Aircraft, Grumman Aircraft & Eng. Co., Bethpage, L. I., N. Y.)	Lt.	Navy
Wails, Elmer Dennis	Midstates Oil Corp., 518 Natl. Bank of Tulsa Bldg., Tulsa, Okla. (Recruit Co., 30th Engrs., Ft. Belvoir, Va.)	Pvt.	Corps of Eng.
Walker, Edward B.	Class No. 98, AA-OCS, Camp Davis, N. C.	O.C.	U. S. Army
Ward, Roland Van	407 E. High, Charlottesville, Va. (c/o Postmaster, San Francisco, Calif.)	Midshipman	Navy
Waring, Waldo William	6310 Wilkins Ave., Pittsburgh, Pa. (c/o Arctic Desert & Tropic Info. Center, Eglin Field, Fla.) (A-0924496)	Capt.	Army Air Force
Waters, Joyce Irene	208 Harris Ave., Hancock, Mich. (U. S. Naval Res., Midshipmen's School (W-R), Northampton, Mass.		WAVE
Watson, Elizabeth A.	5823 Packard St., Los Angeles 35, Calif. (44-W-5(J-5), 318th A.A.F.F.T.D., Avenger Field, Sweetwater, Tex.)		Air W.A.C.
Wells, Harris Peyton, Jr.	220 Minnesota Ave., Buffalo, N. Y. (Co. "A"-101st Eng. Bn., A.P.O. 26, Camp Campbell, Ky.)		Corps of Eng.
Wenberg, Edwin Hugo	Rt. 2, West De Pere, Wis. (A-V S, 239238, Special Devices Depot, 353 W. 57th St., New York, N. Y.)	Ens.	Navy
Wengerd, Sherman A.	Shell Oil Co., Inc., Box 1191, Tulsa, Okla. (155 Homer St., Newton Centre 59, Mass.)	Lt.	Navy
Wharton, Jay B., Jr.	Box 304, Lafayette, La. (D-V, File 318556)	Lt.	Navy
Whatley, James Moulton	155 Egan St., Shreveport, La.	Ens.	Navy
Wheeler, James Albert	c/o M. A. Taylor, Rt. 1, Lorena, Tex. (Marana Basic Flying School, Tucson, Ariz.)		Army Air Force
White, Albert William	Fain-McGaha Oil Corp., 607 Hamilton Bldg., Wichita Falls, Tex. (16th Ferrying Sqn., 5th Ferrying Group, Love Field, Dallas, Tex.)	Sgt.	Army Air Corps
White, Kirk S.	1319 Emporia, Muskogee, Okla.		U. S. Army
Whittinghill, Frank T., Jr.	1930 Freeman Ave., Owensboro, Ky. (U. S. Naval Air Station, Quonset Point, R. I.) (277009, N.R.T.S., King & Prince Hotel, St. Simon's Is., Ga.)	Ens.	Navy
Whorton, Chester D.	Box 311, Coudersport, Pa. (F.P.O., New York, N. Y.)	Lt.	Navy
Wilder, Newell M.	155 Hamilton Park, Lexington, Ky. (Co. A, 9th Inf., Camp McCoy, Wis.)	Capt.	Infantry
Williams, George Arthur	212 S. Zinc St., Deming, N. M.		Navy
Williams, Robert N., Jr.	2606 Chester Lane, Bakersfield, Calif. (359th Engr. Regt. G. S., Camp Claiborne, La.)	Lt.	Corps of Eng.
Willis, Clifford L.	Carter Oil Co., Box 206, Jena, La. (DE-383, F.P.O., New York, N. Y.)	Lt.	Coast Guard
Wilson, James, Jr.	Box, 87, Rocksdale, Tex. (Co. C, 83rd Recon. Bn., 3rd Armd. Div., Camp Polk, La.)	Lt.	Cavalry
Winkler, Hans	104 W. 32nd St., Austin, Tex.	Lt.	Navy
Winzeler, Alvin R.	3617 E. Kellogg, Wichita, Kans. (c/o Postmaster, Seattle, Wash.)	Lt.	Army Air Force
Wiringa, Leon O.	Shell Oil Co., Inc., 2000 Alamo Natl. Bldg., San Antonio, Tex. (U.S.N.R., Fire Control School, Washington, D. C.)	Lt.	Navy
Witherspoon, Edgar	550 Funston Pl., San Antonio, Tex. (91st Group, Brooks Field, San Antonio, Tex.) (O-502429)	Lt.	Army Air Force
Wofford, Henry R., Jr.	234 W. Mistletoe, San Antonio, Tex. (Office of A.C. of S., G2, 8th Corps Area, Fort Sam Houston, Tex.)	Sgt.	Army

Name	*Last Home Address (Military Address)*	*Rank*	*Branch of Service*
Wold, John Schiller	c/o Dr. P. I. Wold, Union College, Schenectady, N. Y. (Columbus Hotel B.O.Q., Sub Chaser Trg. Center, Miami, Fla.)	Lt.	Navy
Woodbury, Homer O.	840 Twelfth St., Boulder, Colo. (Fleet P.O., San Francisco, Calif.)	Ens.	Navy
Woods, Raymond D.	901 Park Ave., W. Helena, Ark.		Army
Woodward, Albert F.	3928 Stockbridge, Los Angeles, Calif. (C.E., 2nd Prov. Bn., E.U.T.C., Camp Claiborne, La.)	Lt.	Corps of Eng.
Woodward, Geo. E., Jr.	2112 N.W. 25th St., Oklahoma City, Okla.		U. S. Navy
Woodward, Truman P.	693 Canal St., Baton Rouge, La. (Battery D, 12th Bn., 4th Regt., F.A.R.T.C., Fort Bragg, N. C.)	Lt.	Field Artillery
Word, Charles F.	310 Jeanette St., Abilene, Tex. (Fleet P.O., San Francisco, Calif.)	Ens.	Navy
Wosk, L. David	228 Broadway, San Diego, Calif.		Army
Wyckoff, J. W.	2954 Oakwood Dr., E. Grand Rapids, Mich. (Savanna Ord. Depot, Proving Ground, Ill.)	Capt.	Ordnance Works
Yarborough, Hunter, Jr.	Navasota, Tex. (Naval Transport Sqn. 6, Dinner Key, Miami, Fla.)	Lt.	Navy
Yenne, Keith A.	Shell Oil Co., Inc., Box 476, Centralia, Ill. (11 Nada Court Apts., Fort Morgan, Colo.)	Ens.	Navy
Young, Keith P.	(Btry. A, 482nd A.A.A. Bn., Camp Hulen, Tex.)	Lt.	Army
Zadik, Jacob William	Preston Hollow, Dallas, Tex. (Hq. Bt., 338th F.A. Bn., 88th Div., Camp Gruber, Okla.)	Capt.	Field Artillery

MEMBERS OF AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS EMPLOYED BY UNITED STATES AND ALLIED COUNTRIES IN CIVILIAN WORK

(December 6, 1943)

Allardyce, Robert L., Jr., Lone Star Ordnance Works, Texarkana, Tex.
Anderson, Carl C., U. S. Bureau of Mines, Box 2529, Amarillo, Tex.
Applin, Paul L., U. S. Geol. Survey, 2317 W. Magnolia, Fort Worth, Tex.
Avery, C. Dwight, U. S. Geol. Survey, 3240 Federal Works Bldg., Washington, D. C.
Bacon, Charles S., U. S. Geol. Survey, Pioche, Nev.
Bain, H. Foster, U. S. Bureau of Mines, Manila, P. I.
Baker, Arthur A., U. S. Geol. Survey, Washington, D. C.
Baker, Norval E., Petroleum Administration for War, Room 1104, 122 E. Forty-second St., New York, N. Y.
Barnett, J. A., U. S. Geol. Survey, Roswell, N. Mex.
Bass, Nathan W., U. S. Geol. Survey, 314 Boston Bldg., Denver 2, Colo.
Bateman, Alan M., Bureau of Economic Warfare, Washington, D. C.
Bateman, Paul C., U. S. Geol. Survey, Bishop, Calif.
Belt, W. E., Jr., U. S. Geol. Survey, Oxford, Miss.
Best, J. Boyd, Petroleum Administration for War, Mellie Esperson Bldg., Houston, Tex.
Billings, Martin Hewett, c/o Non-Metal Economics Div., U. S. Bureau of Mines, Dept. of Interior, Washington, D. C.
Bleyberg, Arnold, Military Geology Unit, U. S. Geol. Survey, Washington, D. C.
Brown, Glen Francis, U. S. Geol. Survey, Box 653, University, Miss.
Brown, Silas C., U. S. Naval Armed Guard Center, Fifty-second St. and First Ave., S. Brooklyn, N. Y.
Butterworth, E. M., Petroleum Administration for War, Foreign Div., 33 E. Forty-eighth St., New York 17, N. Y.
Cannon, Joe, Petroleum Administration for War, 410 Beacon Bldg., Tulsa, Okla.
Carpenter, Charles B., U. S. Bureau of Mines, Dallas 1, Tex.
Cathcart, James B., Jr., U. S. Geol. Survey, Box 1694, Little Rock, Ark.
Cederstrom, D. John, U. S. Geol. Survey, Charlottesville, Va.
Cerkel, J. David, U. S. Geol. Survey, Bin CC, Taft, Calif.
Clapp, Frederick G., 50 Church St., New York, N. Y. (Turkey)
Coates, George H., Navy Department, Washington, D. C.
Coleman, Tom L., U. S. Geol. Survey, Box 976, Oklahoma City, Okla.
Corby, Grant W., Box 2540, Manila, P. I.

Crawford, James Gilmore, U. S. Dept. of the Interior, Box 400, Casper, Wyo.
Creasey, Saville C., U. S. Geol. Survey, Los Angeles, Calif.
Dane, Carle H., U. S. Geol. Survey, Washington 25, D. C.
Darton, N. H., U. S. Geol. Survey, Washington 25, D. C.
Davies, Steven N., U. S. Geol. Survey, Univ. of Calif., Los Angeles, Calif.
DeGolyer, E., Petroleum Reserves, Washington, D. C.
Dickerson, Roy E., Board of Economic Warfare, Washington 25, D. C.
Dobbin, Carroll E., U. S. Geol. Survey, 224 Custom House, Denver, Colo.
Dorr, John van Nostrand, II, U. S. Geol. Survey, Washington, D. C.
Drach, Gertrude M., Petroleum Administration for War, S. Interior Bldg., Washington 25, D. C.
Dumbros, Nicholas G., Petroleum Administration for War, Washington, D. C.
Edson, Fanny Carter, U. S. Geol. Survey, Box 311, Tulsa, Okla.
Erdmann, Charles E., U. S. Geol. Survey, 224 Custom House, Denver 2, Colo.
Espach, Ralph H., U. S. Bureau of Mines, Box 877, Laramie, Wyo.
Fanshawe, John R., Petroleum Administration for War, 320 First Natl. Bank Bldg., Denver, Colo.
Farish, Linn M., 3546 Seventy-fourth St., Jackson Heights, Long Island, N. Y. (Tech. Corps, England)
Farrell, Agnes M., U. S. Geol. Survey, Washington, D. C.
Fender, Hollis B., Dept. of Soil Investigation, Wabash River Ordnance Works, Bloomington, Ind.
Finch, Elmer H., Petroleum Administration for War, New Interior Bldg., Washington, D. C.
Gardner, Julia, U. S. Geol. Survey, Washington, D. C.
George, W. O., U. S. Geol. Survey, Austin, Tex.
Gregersen, Albert, Petroleum Administration for War, 855 Subway Terminal Bldg., 417 S. Hill St., Los Angeles 13, Calif.
Greig, Douglas A., Office of the British Petroleum Representative, 15 Broad St., New York 5, N. Y.
Grove, B. H., Board of Economic Warfare, Washington 25, D. C.
Guthrie, Robert K., U. S. Bureau of Mines, 551 Federal Bldg., Dallas, Tex.
Hage, Conrad O., Geological Survey, Victoria Museum, Ottawa, Ont., Canada
Henbest, Lloyd G., 327 U. S. National Museum, Washington 25, D. C.
Henderson, Charles W., U. S. Bureau of Mines, 515 Custom House, Denver, Colo.
Hendricks, Thomas A., U. S. Geological Survey, Washington 25, D. C.
Henny, Gerard, Army & Navy Y.M.C.A., 921 Beacon St., San Pedro, Calif.
Henson, F. R. S., Iraq Petr. Co., Kirkuk, Iraq
Heroy, William B., Division of Foreign Production, Petroleum Administration for War, Washington, D. C.
Heston, J. Ed, Office of Production Management, Washington, D. C.
Hill, Harry B., U. S. Bureau of Mines, 551 Federal Bldg., Dallas 1, Tex.
Hoffman, M. G., Petroleum Administration for War, Washington 25, D. C.
Hough, Jack L., Bureau of Ordnance, Navy Department, Woods Hole Oceanographic Inst., Woods Hole, Mass.
Hughes, Richard V., Petroleum Administration for War, Washington 25, D. C.
Hume, George S., Geological Survey, Victoria Museum, Ottawa, Ont., Canada
Imbt, Robert F., Board of Economic Warfare, Washington 25, D. C.
Imlay, Ralph W., U. S. Geological Survey, 331 U. S. National Museum, Washington 25, D. C.
Jones, Paul Hastings, U. S. Geological Survey, Ground Water Div., Box 8315, University Station, Baton Rouge, La.
Kane, William G., Apt. 711, Mexico, D. F., Mexico
Keeler, Clifton M., c/o Food Distribution Administration, Box 672, San Juan, Puerto Rico
Kerstetter, Dale D., Naval Ordnance Lab., Navy Yard, Washington, D. C.
King, Philip B., U. S. Geological Survey, Washington 25, D. C.
Knechtel, M. M., U. S. Geological Survey, 4230 N. Interior Bldg., Washington 25, D. C.
Kramer, William B., U. S. Geological Survey, 224 Custom House, Denver, Colo.
Krumbein, William C., Beach Erosion Board, Little Falls Rd., N. W., Washington, D. C.
Lang, W. B., U. S. Geological Survey, Washington 25, D. C.
Larrabee, David M., U. S. Geological Survey, Box 1106, Albany, N. Y.
Larsen, Raymond M., U. S. Geological Survey, 305 Federal Bldg., Casper, Wyo.
Laves, U. R., Machinery Section Head, Regional Office, Office of Price Administration, Fidelity Bldg., Dallas, Tex.
Lee, Marvin, Petroleum Administration for War, Chicago, Ill.
Lewis, J. Volney, c/o H. B. McCoy, Mining Division, War Production Board, Washington, D. C.
Link, Theodore A., Dir. Geol. Investigation, U. S. Government in Northern Canada, Calgary, Alta., Canada
Lott, Frederick S., Naval Ordnance Lab., U. S. Navy Yard, Washington, D. C.
Loughlin, Gerald F., U. S. Geological Survey, Washington, D. C.

Lynton, Edward D., Board of Economic Warfare, A.P.O. 759, NAEB, c/o Postmaster, New York, N. Y.
MacNeil, F. Stearns, U. S. National Museum, Washington 25, D. C.
Maher, John C., U. S. Geological Survey, Baton Rouge, La.
Martin, B. G., Petroleum Administration for War, 245 Mellie Esperson Bldg., Houston, Tex.
Maverick, Phillip, Securities & Exch. Com., 103 U. S. Courthouse, Fort Worth, Tex.
Maxwell, Ross A., Region III, Headquarters, National Park Service, Santa Fe, N. Mex.
McCammon, J. H., Petroleum Administration for War, Div. of Natural Gas & Gasoline, Washington, D. C.
McWhirt, Burr, Income Tax Unit, Room 3232, Internal Revenue Bldg., Washington, D. C.
Merritt, Roy W., American Embassy, Bogota, Colombia, S. A.
Millard, William John, Principal Production Specialist for the B.E.W. in Brazil. c/o United States Embassy, Rio de Janeiro, Brazil, S. A.
Miller, John Robson, U. S. Geological Survey, Box 42, Portland, Conn.
Milner, Charles A., Jr., National Park Service, Box 325, Ardmore, Okla.
Miser, Hugh D., U. S. Geological Survey, Washington 25, D. C.
Monroe, Watson H., U. S. Geological Survey, Oxford, Miss.
Montgomery, Don D., Ordnance Dept., Aberdeen Proving Grounds, Md.
Needham, Claude E., Economics & Statistics Br., U. S. Bureau of Mines, Washington 25, D. C.
Ongley, Montague, Geological Survey, 156 Terrace, Wellington, N. Z.
Page, Lincoln R., U. S. Geological Survey, Box 71, Custer, S. Dak.
Parker, Gerald Gordon, U. S. Geological Survey, 1772 S. W. Twenty-first Terrace, Miami, Fla.
Payne, Thomas G., U. S. Geological Survey, Department of the Interior, Alaskan Branch, Washington, D. C.
Peden, William M., 1521 First Ave., N., Great Falls, Mont. (U. S. Geol. Survey)
Pierce, William Gamewell, U. S. Geological Survey, Washington 25, D. C.
Pike, Sumner T., Securities & Exch. Com., Rittenhouse Square, Philadelphia, Pa.
Reeside, John B., Jr., U. S. Geol. Survey, Washington 25, D. C.
Reeves, Frank, Petroleum Administration for War, Washington 25, D. C.
Revelle, Roger, 9201 Flower Ave., Silver Springs, Maryland
Richards, Ralph W., U. S. Geol. Survey, Washington 25, D. C.
Robbins, H. Weston, Soil Conservation Service, Torrington, Wyo.
Rodgers, John, U. S. Geol. Survey, Washington 25, D. C.
Rose, Nicholas A., U. S. Geol. Survey, Houston, Tex.
Rothrock, Howard E., Natl. Park Service, U. S. Dept. of the Interior, Washington, D. C.
Russell, R. Dana, Univ. of California, Div. of Natl. Defense Research, U. S. Navy Radio & Sound Laboratory, San Diego, Calif.
Sayre, A. Nelson, U. S. Geol. Survey, Washington 25, D. C.
Scherer, Oliver J., Soil Conservation Service, Lincoln, Neb.
Schwabrow, John R., U. S. Geol. Survey, Box 400, Casper, Wyo.
Sears, Julian D., U. S. Geol. Survey, Washington 25, D. C.
Severy, C. L., U. S. Bureau of Mines, 1401 Walker Bank Bldg., Salt Lake City 1, Utah
Shelton, John S., U. S. Geol. Survey, Washington 25, D. C.
Shearer, Harold K., Board of Economic Warfare, Rio de Janeiro, Brazil, S. A.
Sherbondy, William E., U. S. Geol. Survey, Denver, Colo.
Sims, Paul K., U. S. Geol. Survey, Metaline Falls, Wash.
Singewald, Joseph T., Jr., Bureau of Economic Warfare, Washington, D. C.
Singewald, Quentin D., Bureau of Economic Warfare, Univ. of Rochester, Rochester, N. Y.
Sinnott, Allen, U. S. Geol. Survey, Long Beach, Calif.
Smith, J. Fred, Jr., U. S. Geol. Survey, Dallas, Tex.
Sohn, Israel G., U. S. Geol. Survey, Payton Bldg., Spokane, Wash.
Somers, George B., 4517 Thirty-fourth St., S., Arlington, Va.
Speed, C. D., Jr., Petroleum Administration for War, Washington, D. C.
Spice, William H., Jr., 2101 Alamo Natl. Bldg., San Antonio, Tex.
Spratt, Robert Elmer, U. S. Geol. Survey, Washington 25, D. C.
Stephenson, L. W., U. S. Geol. Survey, Washington 25, D. C.
Stipp, Thomas F., U. S. Geol. Survey, Conservation Branch, Washington 25, D. C.
Storm, L. W., U. S. Bureau of Mines on Mexican Resources, Apt. 590, Mexico D. F., Mex.
Stringfield, V. T., U. S. Geol. Survey, Washington 25, D. C.
Sullwold, Harold H., Jr., U. S. Geol. Survey, Cuba, N. Mex.
Summerson, Charles H., U. S. Geol. Survey, New Philadelphia, Ohio
Sumner, Walton, U. S. Bureau of Mines, Longview, Tex.
Taylor, Josiah, Dept. of Terrestrial Magnetism, 5241 Broad Branch Rd., N. W., Washington, D. C.
Thompson, Raymond M., U. S. Geol. Survey, Dept. of Geology, Univ. of Wyoming, Laramie, Wyo.

Townsend, Rex, Office of Petroleum Adviser, Dept. of State, Washington, D. C.
Trager, Earl A., Bureau of Economic Warfare, Washington, D. C.
Trask, Parker D., U. S. Geol. Survey Washington 25, D. C.
Ulrich, E. O., National Museum, Washington, D. C.
Van Orstrand, C. E., U. S. Geol. Survey, Washington, 25, D. C.
Vaughan, T. Wayland, 427 U. S. Natl. Museum, Washington, D. C.
Wadsworth, A. H., Jr., U. S. Geol. Survey, Bay City, Tex.
Waring, Gerald A., U. S. Geol. Survey, Washington 25, D. C.
Weeks, A. W., Petroleum Administration for War, 320 First Natl. Bank Bldg., Denver, Colo.
Wellings, F. E., Iraq Petr. Co., Katamon, Jerusalem, Palestine
White, Paul C., Federal Power Commission, 18th & K. St. Annex, Washington, D. C.
White, Tell T., Securities & Exchange Commission, Rittenhouse Square, 18th & Locust St., Philadelphia, Pa.
Whittier, William H., Special Agent, Div. of Investigations, Dept. of the Interior, Salt Lake City, Utah
Wilson, Ivan F., U. S. Geol. Survey, Baja Calif., Mex.
Wrather, William E., Director, U. S. Geol. Survey, Washington, 25, D. C.
Wright, Randall, U. S. Engineer Office, Box 51, Port Allen, La.
Wright, William Josiah, Dept. of Lands and Mines, Fredericton, N. B., Canada
Zapp, Alfred D., U. S. Geol. Survey, Americus, Ga.
Zorichak, Joseph J., Petroleum Administration for War, Denver, Colo.

CODE OF ETHICS OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS

OBJECT. The object of this Association is to promote the science of geology, especially as it relates to petroleum and natural gas; to promote the technology of petroleum and natural gas and to encourage improvements in the methods of exploring for and exploiting these substances; to foster the spirit of scientific research amongst its members; to disseminate facts relating to the geology and technology of petroleum and natural gas; to maintain a high standard of professional conduct on the part of its members; and to protect the public from the work of inadequately trained and unscrupulous persons posing as petroleum geologists. (Constitution, Article II.)

ARTICLE I. GENERAL PRINCIPLES

SECTION 1. The practice of petroleum geology is a profession. It is the duty of those engaged in it to be guided by the highest standards of professional conduct and to subordinate reward and financial gain thereto.

SEC. 2. The confidence of the public and of the oil industry can be won and held only by the practice of the highest ethical principles.

SEC. 3. Honesty, integrity, fairness, candor, fidelity to trust, inviolability of confidence, and conduct becoming a gentleman are incumbent upon every member of the Association.

ARTICLE II. RELATION OF GEOLOGIST TO PUBLIC AND PROFESSION

SECTION 1. A geologist should avoid and discourage sensational, exaggerated, and unwarranted statements, especially those that might induce participation in unsound enterprises.

SEC. 2. A geologist should not knowingly permit the publication of his reports or maps for the purpose of raising funds without legitimate and sound development in view.

SEC. 3. A geologist may accept for his services in the making of a report an interest in the property reported on, but it is desirable that the report state the fact of the existence of the interest.

SEC. 4. A geologist should not give an opinion or make a report without being as fully informed as might reasonably be expected, considering the purpose for which the information is desired. The opinion or report should make clear the conditions under which it is made.

SEC. 5. A geologist may publish simple and dignified business, professional, or announcement cards, but should not solicit business by other advertisements, or through agents, or by furnishing or inspiring exaggerated newspaper or magazine comment. The most worthy advertisement is a well merited reputation for professional ability and fidelity. This can not be forced, but must be the outcome of character and conduct.

ARTICLE III. RELATION OF GEOLOGIST TO EMPLOYER

SECTION 1. A geologist should protect, to the fullest extent possible, the interests of his employer so far as consistent with the public welfare and his professional obligations.

SEC. 2. A geologist who finds that his obligations to his employer conflict with his professional obligations should notify his employer of that fact. If the objectionable condition persists, the geologist should sever his connection with his employer.

SEC. 3. A geologist should not allow himself to become or remain identified with any enterprise of questionable character.

SEC. 4. A geologist should make known to his prospective employer any oil or gas interest which he holds in the region of his prospective employment.

SEC. 5. A geologist, while employed, should not directly or indirectly acquire any present or prospective oil or gas interest without the express consent of his employer.

SEC. 6. A geologist retained by one client, should, before accepting engagement by another, notify them of this affiliation, if in his opinion the interests might conflict.

SEC. 7. A geologist who has made an investigation for a client should not, without the client's consent, seek to profit from the economic information thus gained, or report on the same subject for another client, until the original client has had full opportunity to act on the report.

SEC. 8. A geologist should not accept direct or indirect compensation from both buyer and seller, without consent of both parties; or from parties dealing with his employer without the employer's consent.

SEC. 9. A geologist should observe scrupulously the rules, customs, and traditions of his employer as to the use or giving out of information or the acquisition of interests, both while employed and thereafter; and, except as permitted by such rules, customs, and traditions or by the consent of the employer, he should not seek to profit directly or indirectly from the economic information gained while so employed.

SEC. 10. A geologist employed by a State geological survey should not permit private professional work or the holding of private mineral interests in the state to interfere with his duty to the public or to lessen the confidence of the public in the survey. The preferable course is to avoid such private work and interests.

SEC. 11. A geologist should not divulge information given him in confidence.

ARTICLE IV. RELATION OF GEOLOGIST TO OTHER GEOLOGISTS

SECTION 1. A geologist should not falsely or maliciously attempt to injure the reputation or business of a fellow geologist.

SEC. 2. A geologist should not knowingly compete with a fellow geologist for employment by reducing his customary charge.

SEC. 3. A geologist should give credit for work done to those, including his assistants, to whom credit is due.

ARTICLE V. DUTY TO THIS ASSOCIATION

SECTION 1. Every member of the Association should aid in preventing the election to membership of those who lack moral character or the required education and experience.

SEC. 2. A member of this Association who has definite evidence of the violation of the established principles of professional ethics by another should report the facts to the executive committee.

JOINT ANNUAL MEETING, DALLAS, MARCH 21–23, 1944

A. RODGER DENISON[1]
Tulsa, Oklahoma

ANNOUNCEMENT

The 29th annual meeting of the American Association of Petroleum Geologists, the 14th annual meeting of the Society of Exploration Geophysicists, and the 18th annual meeting of the Society of Economic Paleontologists and Mineralogists will be held at Dallas, Texas, March 21, 22, and 23, 1944, at the invitation of the Dallas Petroleum Geologists. The Baker Hotel is headquarters.

SECOND WAR-TIME CONFERENCE

This meeting will be the second war-time joint conference of the three exploratory societies. Recognizing the critical position of petroleum and its products in winning the war, they accept the responsibility of finding new supplies to replace the diminishing reserves. The program of this meeting is being organized to bring to the members, through special speakers, conferences, and discussions, new ideas and methods for improving exploration efficiency. There will be a re-examination of prospective areas in the United States and other parts of the world. The sessions are to be confined strictly to business and technical matters. There will be no banquet, dance, golf tournament, or field trips. Because of greatly restricted hotel space, there will be no possibility of accommodating wives.

The program will again be restricted to subjects of broad general interest and no papers of local interest will be placed on the oral program. Titles of papers, with abstracts, for inclusion in the printed program, are invited and should be submitted by February 15 to A.A.P.G. headquarters, Box 979, Tulsa 1, Oklahoma.

NOTICE OF MEETING TO RENEW ASSOCIATION CERTIFICATE OF INCORPORATION

TO THE MEMBERS OF THE A.A.P.G.—On Thursday, March 23, 1944, at 4:00 P.M., the annual business meeting of the Association will be held in the Ball Room on the Mezzanine of the Baker Hotel, Dallas. At this meeting the members will be asked to consider the renewal of the Certificate of Incorporation of the Association, which certificate expires under the statutes of the State of Colorado, on April 23, 1944.

OUTLINE OF PROGRAM

MARCH 21, TUESDAY	A.M.	Standing and special committees; research committee conferences S.E.G. business and technical sessions
	P.M.	Annual business meeting; research conferences S.E.G. sessions
	NIGHT	Research symposium
MARCH 22, WEDNESDAY	A.M.	Reviews of 1943; presidential addresses
	P.M.	Special speakers
	NIGHT	Special guest speaker
MARCH 23, THURSDAY	A.M.	Re-examination of prospective regions; world reserves S.E.P.M. business and technical sessions
	P.M.	Symposium on foreign regions S.E.P.M. business and technical sessions

EXHIBITS

The usual exhibit of scientific equipment and exploratory methods will be arranged insofar as practical. Also, space will be available for map displays of educational institutions, geological societies, and State surveys. Inquiries should be directed to the A.A.P.G., Box 979, Tulsa 1, Oklahoma.

[1] President of the Association.

TRANSPORTATION

If you do not have your own means of transportation, and plan to travel by Pullman: *first*, be certain that you can attend the meeting; *second*, make your Pullman reservations, both going and return, well in *advance; third*, cancel reservations immediately if you find you can not use them. The meeting closes a day earlier in the week, this year, in order to avoid week-end travel congestion.

HOTELS

Hotel rooms are available only in limited number. You should make your own reservation *now*, direct with the hotel of your choice; request the hotel for confirmation; do not go to the meeting on the mere chance or hope of getting a hotel room; *go only if you hold hotel confirmation of reservation;* if you find you can not attend, cancel immediately any reservation you have made. Hotel rooms and service are already seriously taxed. It will be necessary in many cases for members to double up in room occupancy. Many former single rooms will contain two beds. Select a friend to share a double room with you. This meeting and the attendant demand on transportation and hotel facilities are justified on the grounds that it is a conference of essential technical men in a critical activity of the war effort.

The chairman of the hotel and housing committee is Eugene McDermott, Geophysical Service, Inc., 1311 Republic Bank Building, Dallas, Texas. If you are unable to find hotel or other housing accommodations the committee will assist you in every way possible.

Hotel	*Rooms*	*Single*	*Double*
Baker Hotel (Headquarters)	700	$2.50 up	$4.00 up
Adolphus Hotel (Opp. Headquarters)	825	2.50 up	4.00 up
White Plaza (4 Blocks from Hdqs.)	300	2.00–4.00	3.00–6.00
Jefferson Hotel (6 Blocks from Hdqs.)	450	2.00 up	2.50 up
Cliff Towers Zangs and Colorado Sts.	450	2.00 up	3.00 up
Mayfair Hotel 723 N. St. Paul	150	2.50 up	2.50 up
Melrose Hotel 3015 Oak Lawn Ave.	325	3.00 up	4.00 up
Stoneleigh Hotel Apt. 2927 Maple Ave.	400	3.00–7.50	4.50–10.00
Maple Terrace 3001 Maple Ave.	400	3.00–7.50	4.50–10.00
Tourist Courts			
Seventy-Seven Ranch 2100 Lucas Drive		Grand Lodge Tourist Court Zangs Blvd.	
El Rancho-Tel 6131 Hines Blvd.		Ross Avenue Courts 3629 Ross Ave.	
Motor Inn Hotel Highway I, Ft. Worth Cutoff		Mission Courts 500 West Commerce St.	

OFFICERS OF DALLAS PETROLEUM GEOLOGISTS

President, Joseph M. Wilson, Continental Building
Vice-Pres., Henry C. Cortes, Magnolia Petroleum Company
Secy.-Treas., H. C. Vanderpool, Seaboard Oil Company

ANNUAL MEETING COMMITTEE CHAIRMAN

TECHNICAL PROGRAM

Chairman, F. H. Lahee, Sun Oil Company
Co-Chairman, S. A. Thompson, Magnolia Petroleum Company

LOCAL ARRANGEMENTS

General Chairman, Joseph M. Wilson, Continental Building
Technical Arrangements, Charles B. Carpenter, U. S. Bureau of Mines
Hotels and Housing, Eugene McDermott, Geophysical Service, Inc.
Registration, Lewis W. MacNaughton, Continental Building
Reception, Dilworth S. Hager, Liberty Bank Building
Educational Exhibits, Edgar Kraus, Atlantic Refining Company
Finance, H. C. Vanderpool, Seaboard Oil Company
Publicity, J. Edward Morrow, Dallas *News*
Publications, Sam M. Aronson, Magnolia Building
S.E.P.M., James A. Waters, Sun Oil Company
S.E.G., Cecil H. Green, Geophysical Service, Inc.

JAPANESE JOURNALS NEEDED

The following Japanese journals and publications have not been received by the principal libraries of this country, but it is possible that separates of some of the articles contained therein may have been sent to individual American geologists and paleontologists.

1. *Contributions from the Institute of Geology and Paleontology, Tohoku Imperial University*, Sendai, Japan. Nos. 1–32 (1921–39, inclusive). (In Japanese language—not to be confused with Science Reports of this same university).
2. *Bulletin of the Tropical Industrial Institute*, Palau. Vol. 1 (1938 to date).
3. *Jubilee Publication in Commemoration of Professor H. Yabe—60th Birthday*, Vol. 2 (1940).

Some of this material is urgently needed. If any of these publications is available for loan or for photographing, please notify promptly the Chairman, Division of Geology and Geography, National Research Council, 2101 Constitution Avenue, Washington, D. C.

BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 28, NO. 1 (JANUARY, 1944), PP. 169-172

AT HOME AND ABROAD

CURRENT NEWS AND PERSONAL ITEMS OF THE PROFESSION

JOHN H. NELIMARK has resigned from the employ of the Darby Petroleum Corporation to become engaged in geological consulting practice. His home address is 1201 South Atlantic Place, Tulsa, Oklahoma.

MAJOR HAROLD H. ARNOLD, formerly division geologist for The Texas Company at Tulsa, Oklahoma, was awarded a Silver Star for gallantry in action in the Tunisian campaign.

C. W. SANDERS, after 17 years with the Shell group, has resigned as research geologist to open a geological consulting office in Houston, Texas. His address is 3428 Wickersham Lane.

DAVID H. NEWLAND, former State geologist of New York for more than a decade, died on October 18, 1943, at the age of 71 years.

LOVIC P. GARRETT, president of the Association in 1931, vice-president of the Gulf Oil Corporation, died at Houston, Texas, December 13, 1943, at the age of 63 years.

RALPH C. HOLMER has resigned as assistant physicist at the Charleston Navy Yard to work for The California Company as a geological observer on a geophysical crew. His address is 1818 Canal Building, New Orleans, Louisiana.

L. K. LANCASTER, formerly with the Tide Water Associated Oil Company, has joined the Hunt Oil Company, Shreveport, Louisiana.

JAMES L. MARTIN has left the employ of the Louisiana Geological Survey. He is working for the Sinclair Prairie Oil Company at Tallahassee, Florida.

WILLIAM I. MAYFIELD, formerly with the Petty Geophysical Engineering Company, San Antonio, Texas, completed his Navy training as Ensign and was recently stationed at the U. S. Naval Armed Guard Center, New Orleans, Louisiana, awaiting assignment as commander of a Navy gun crew aboard an American merchant ship.

DONALD M. WEST, recently with the Socony-Vacuum Oil Company, is with the Island Development Company, Charlottetown, Prince Edward Island, Canada.

JOHN B. KLECKER, recently with the Atlantic Refining Company of Cuba, has been transferred to Caracas, Venezuela, to become resident geologist for the Venezuelan Atlantic Refining Company.

D. C. SHAY is in Cody, Wyoming, as geologist for the Barnsdall Oil Company in the Rocky Mountain district.

CHESTER A. BAIRD, who has been in Venezuela for many years, has left the services of the Mene Grande Oil Company, Caracas. His residence is 4220 Winchester Pike, Canal Winchester, Ohio.

A. N. MACKENZIE has left the Cie de Petroleo Ganso Azul, Lima, Peru, and has joined the Petroleum Administration for War as assistant director of the Foreign Production Division, Washington, D. C.

HENRY HOWE ROBBINS SHARKEY is with a United States Geological Survey field party

engaged in stratigraphic studies in the Rocky Mountain area in connection with petroleum exploration. His address is U.S.G.S., Science Hall, University of Wyoming, Laramie, Wyoming.

KATHERINE CARMAN, recently with the Petroleum Administration for War, is with the Great Lakes Carbon Corporation, West Frankfort, Illinois.

JOHN TRENCHARD has left the Army Engineers and is temporarily located at Evansville, Indiana, drilling wells in Illinois for Whisenant and Trenchard.

A. J. BAUERNSCHMIDT of the Magnolia Petroleum Company, Houston, spoke at the meeting of the South Texas Geological Society, San Antonio, Texas, December 13. His subject was "Geology of West Ranch Field, Jackson County, Texas."

The Houston Geological Society listened to CAREY CRONEIS, of the University of Chicago, December 13. His talk was "Science in the Future."

New officers of the Society of Economic Paleontologists and Mineralogists have been elected by mailed ballot for the year beginning, March, 1944: president, DONALD D. HUGHES, Stanford University, California; vice-president, HERSHAL C. FERGUSON, Esperson Building, Houston, Texas; H. B. STENZEL (re-elected), Bureau of Economic Geology, Austin, Texas.

At the evening program of the Rocky Mountain Association of Petroleum Geologists at Denver, Colorado, on Monday, December 6, 1943, the following officers were elected for the ensuing year: president, BEN H. PARKER, Colorado School of Mines and Frontier Refining Company; 1st vice-president, DART WANTLAND, Colorado School of Mines; 2nd vice-president, WILLIAM B. KRAMER, U. S. Geological Survey; secretary-treasurer, A. W. WEEKS, Petroleum Administration for War, 320 First National Bank Building. Luncheons are held every Friday noon. Evening dinner (6:15) and program meetings (7:30) are held on the first Monday of each month or by announcement. All meetings are at the Cosmopolitan Hotel.

MAYNARD ROGERS has been discharged from the Army Air Corps and has resumed his consulting practice at 2909 East Mulberry Street, Evansville, Indiana.

J. WILLIAM SCHMOTZER is district geologist for the Arkansas Fuel Oil Company, 1410 Tower Building, Jackson 1, Mississippi.

After more than 20 years in the geological and land-and-lease divisions of the Standard Oil Company of California, 12 years of which were spent in Brazil, Argentina, Venezuela, and Colombia, THEO H. CROOK has been retired, and since July 1 has been lecturing in the department of geological sciences at the University of California, at Berkeley.

J. HARLAN JOHNSON, associate professor of geology, Colorado School of Mines, Golden, Colorado, presented a paper on "Ordovician Stratigraphy of the Sawatch Range of Colorado," before the Rocky Mountain Association of Petroleum Geologists, at Denver, December 6.

DISTINGUISHED LECTURE TOURS IN NOVEMBER AND DECEMBER

During the month of November, three speakers appeared before the affiliated societies under the auspices of the distinguished lecture committee.

CLAUDE E. ZOBELL, geomicrobiologist of the Scripps Institution of Oceanography and Director of A. P. I. Project 43A, discussed "The Influence of Bacterial Activity on Petroleum Deposits and Products" before the following coöperative societies.

November 9—Illinois Geological Society at Mt. Vernon
November 10—Tulsa Geological Society at Tulsa
November 11—Tulsa Geological Society at Bartlesville
November 12—Fort Worth Geological Society at Fort Worth
November 13—West Texas Geological Society at Midland

RICHARD JOEL RUSSELL, professor of geology at Louisiana State University, lectured on "Quaternary Delta Succession in the Lower Mississippi Valley" or "Origin of Lower Mississippi Valley Loess" before these societies.

November 17—Mississippi Geological Society at Jackson
November 19—Indiana-Kentucky Geological Society at Evansville
November 22—Michigan Geological Society at Lansing
November 24—Panhandle Geological Society at Amarillo
November 26—Fort Worth Geological Society at Fort Worth
November 29—Houston Geological Society at Houston
November 30—Corpus Christi Geological Society at Corpus Christi

EZEQUIEL ORDONEZ, distinguished Mexican geologist, came to the United States to deliver a series of illustrated lectures on the new volcano, Paricutin, before the affiliated societies. Because of illness his trip was curtailed, and he was forced to return to Mexico City after speaking before the following societies.

November 29—South Texas Geological Society at San Antonio
November 30—Latin-American Institute at Austin
December 1 —Dallas Petroleum Geologists at Dallas
December 2 —Fort Worth Geological Society at Fort Worth

In the place of Dr. Ordonez, FRED M. BULLARD, professor of geology at the University of Texas, completed the tour among the affiliated societies, discussing the same subject during the month of December before these societies.

December 3—West Texas Geological Society at Midland
December 6—Tulsa Geological Society at Tulsa
December 7—Kansas Geological Society at Wichita Annual Meeting
December 8—Shawnee and Oklahoma City Geological Societies at Shawnee
December 10—North Texas Geological Society at Wichita Falls
December 13—Shreveport Geological Society at Shreveport
December 14—Mississippi Geological Society at Jackson
December 15—New Orleans Geological Society at New Orleans
December 16—South Louisiana Geological Society at Lake Charles
December 17—Houston Geological Society at Houston

JOHN L. FERGUSON, *chairman*
Distinguished lecture committee

HOWARD CLARK is in charge of the United States Geological Survey stratigraphic studies of eastern Colorado and western Kansas and adjoining states. Associated with him are RALPH KING, FANNY C. EDSON, and OLIVE HOFFMAN.

A. E. BRAINERD, of the Continental Oil Company, discussed "The Pre-Pennsylvanian Stratigraphy of the Front Range in Colorado," at the meeting of the Rocky Mountain Association of Petroleum Geologists, at Denver, January 3.

MAX W. BALL, consulting petroleum geologist and engineer of Denver Colorado, has an article in the December *American Bar Association Journal*, entitled "The Expert Witness."

S. H. KNIGHT, professor of geology at the University of Wyoming, gave a chalk talk on "Tertiary History of the Wyoming Basin," before the Tulsa Geological Society, January 6.

ALVA C. ELLISOR, of the Humbel Oil and Refining Company, read a paper on "The Anahuac Formation," at the meeting of the Houston Geological Society, on January 6.

An erroneous statement of the position of ELWYN R. OWEN appeared in the December *Bulletin*. He is an assistant in the office of ROY P. LEHMAN who is district geologist for the Phillips Petroleum Company at Shawnee, Oklahoma.

HOMER M. WILSON, of Marathon, Texas, died on July 14, 1943.

J. A. CULBERTSON is division geologist with the Continental Oil Company, 610 Oil and Gas Building, Houston, Texas.

CHARLES E. DECKER, professor of paleontology at the University of Oklahoma, was recently honored by election to a research professorship. The chair of research professor is awarded to a person who "shall have made distinguished contribution to knowledge, and who must have demonstrated over a period of years to the learned world his vigorous leadership in his field." The position carries a salary of $5,000 a year and suitable research aid. Dr. Decker, having been retired on half pay, will receive half of the stipend. He plans to use his research assistance in field work. Dr. Decker joined the geological faculty at the University of Oklahoma in 1916, and since 1925 he has been full professor of paleontology. He was secretary-treasurer of the A.A.P.G. from 1919 to 1926, the longest tenure of that office by one man.

ARNOLD H. BLEYBERG, for many years with the Fohs Oil Company, Houston, Texas, has been appointed geologist with the Military Geology Unit, U. S. Geological Survey, Washington, D. C.

The Kansas Geological Society, Wichita, Kansas, held its annual meeting, December 7, and the following officers were elected for the year 1944: president, LEO R. FORTIER, Alpine Oil and Royalty Company, Inc.; vice-president, VIRGIL B. COLE, Gulf Oil Corporation; secretary-treasurer, DELBERT J. COSTA, Superior Oil Company of California. The Kansas Geological Society maintains the Well Log Bureau under the managership of HARVEL E. WHITE, 412 Union National Bank Building.

S. F. SHAW, consulting engineer of San Antonio, who has been associate professor in petroleum engineering at the Agricultural and Mechanical College of Texas until recently, was in Calgary, Canada, during January.

CARL H. BROEDEL has left the employ of the Anaconda Copper Mining Company, Montana. He is with the Continental Oil Company, Wichita Falls, Texas.

RALPH G. NICHOLS, formerly with the Adams Oil and Gas Company, Houston, Texas, is in the employ of the Superior Oil Company of California, Houston.

ARTHUR W. NAUSS may be addressed in care of the Imperial Oil Canol Project, Box 129, Edmonton, Alberta, Canada.

EDWARD J. FOLEY, recently with the Standard Oil Company of New Jersey, is with the Imperial Oil Canol Project, Edmonton.

CLENON C. HEMSELL has left the Columbian Carbon Company. He is geologist for the Shamrock Oil and Gas Corporation, Amarillo, Texas.

BRUCE WHITCOMB is with the Seaboard Oil Company, Dallas, Texas.

CHARLES R. CANFIELD, of the Stanolind Oil and Gas Company, has moved from Midland, to Wichita Falls, Texas, to have charge of geological work there.

HEWLETT A. RUSSELL has resigned from the Standard Oil Company of Texas to operate independently at Graham, Texas.

PROFESSIONAL DIRECTORY

Space for Professional Cards Is Reserved for Members of the Association. For Rates Apply to A.A.P.G. Headquarters, Box 979, Tulsa, 1, Oklahoma

CALIFORNIA

J. L. CHASE
Geologist — *Geophysicist*
529 East Roosevelt Road
LONG BEACH CALIFORNIA
Specializing in Magnetic Surveys

PAUL P. GOUDKOFF
Geologist
Geologic Correlation by Foraminifera and Mineral Grains
799 Subway Terminal Building
LOS ANGELES, CALIFORNIA

JEROME J. O'BRIEN
Petroleum Geologist
Examinations, Reports, Appraisals
500 Lane Mortgage Bldg.
208 West Eighth St.
McCARTHY & O'BRIEN Los Angeles, Calif.

ERNEST K. PARKS
Consultant in
Petroleum and Natural Gas Development
and
Engineering Management
614 S. Hope St.
LOS ANGELES, CALIFORNIA

HENRY SALVATORI
Western Geophysical Company
711 Edison Building
601 West Fifth Street
LOS ANGELES, CALIFORNIA

RICHARD L. TRIPLETT
Core Drilling Contractor
WHitney 9876 1014 West View St
LOS ANGELES 16, CALIF.

VERNON L. KING
Petroleum Geologist and Engineer
707 South Hill Street
LOS ANGELES, CALIFORNIA
Vandike 7087

COLORADO

C. A. HEILAND
Heiland Research Corporation
130 East Fifth Avenue
DENVER, 9, COLORADO

COLORADO

HARRY W. OBORNE
Geologist
304 Mining Exchange Bldg. 230 Park Ave.
Colorado Springs, Colo. New York, N.Y.
Main 7525 Murray Hill 9-3541

EVERETT S. SHAW
Geologist - Engineer
3131 Zenobia Street
DENVER, COLORADO
Exploration Surveys

ILLINOIS

ELMER W. ELLSWORTH
Consulting Geologist
201 Grand Theatre Building
132 North Locust Street
CENTRALIA, ILLINOIS
Now in military service

L. A. MYLIUS
Geologist *Engineer*
New Fowler Bldg., 311 East Broadway
Box 264, Centralia, Illinois

LOUISIANA

WILLIAM M. BARRET, INC.
Consulting Geophysicists
Specializing in Magnetic Surveys
Giddens-Lane Building SHREVEPORT, LA.

NEW YORK

FREDERICK G. CLAPP
Consulting Geologist
Examinations, Reports, Appraisals, Management
50 Church Street, New York
Chickasha, Oklahoma

BROKAW, DIXON & McKEE
Geologists *Engineers*
OIL—NATURAL GAS
Examinations, Reports, Appraisals
Estimates of Reserves
120 Broadway, New York
Gulf Building, Houston

OHIO

JOHN L. RICH
Geologist
Specializing in extension of "shoestring" pools
University of Cincinnati
Cincinnati, Ohio

OKLAHOMA

ELFRED BECK
Geologist

717 McBirney Bldg.
TULSA, OKLA.

Box 55
DALLAS, TEX.

GEOLOGIC AND STRUCTURAL MAPPING FROM AERIAL PHOTOGRAPHS

LOUIS DESJARDINS
Aero-Geologist

Tulsa, Oklahoma

Temporary Address:
Box 129, Edmonton, Alberta

R. W. Laughlin L. D. Simmons

WELL ELEVATIONS

LAUGHLIN-SIMMONS & CO.
615 Oklahoma Building
TULSA OKLAHOMA

CLARK MILLISON
Petroleum Geologist
Philtower Building
TULSA OKLAHOMA

A. I. LEVORSEN
Petroleum Geologist
221 Woodward Boulevard
TULSA OKLAHOMA

G. H. WESTBY
Geologist and Geophysicist
Seismograph Service Corporation
Kennedy Building Tulsa, Oklahoma

C. L. WAGNER
Consulting Geologist
Petroleum Engineering
Geophysical Surveys
2259 South Troost Street
TULSA OKLAHOMA

PENNSYLVANIA

HUNTLEY & HUNTLEY
Petroleum Geologists and Engineers
L. G. HUNTLEY
J. R. WYLIE, JR.
Grant Building, Pittsburgh, Pa.

TEXAS

JOHN A. GILLIN
National Geophysical Company
Tower Petroleum Building
Dallas, Texas

TEXAS

JOSEPH L. ADLER
Geologist and Geophysicist
Contracting Geophysical Surveys in Latin America
Independent Exploration Company
Esperson Building Houston, Texas

D'ARCY M. CASHIN
Geologist *Engineer*
Specialist, Gulf Coast Salt Domes
Examinations, Reports, Appraisals
Estimates of Reserves
705 Nat'l. Standard Bldg.
HOUSTON, TEXAS

TEXAS

CUMMINS, BERGER & PISHNY
Consulting Engineers & Geologists
Specializing in Valuations
1603 Trinity Bldg. Fort Worth 2, Texas
Ralph H. Cummins
Walter R. Berger
Chas. H. Pishny

E. DEGOLYER
Geologist
Esperson Building
Houston, Texas
Continental Building
Dallas, Texas

ALEXANDER DEUSSEN
Consulting Geologist
Specialist, Gulf Coast Salt Domes
1006 Shell Building
HOUSTON, TEXAS

DAVID DONOGHUE
Consulting Geologist
Appraisals - Evidence - Statistics
Fort Worth National Bank Building
FORT WORTH, TEXAS

JOHN M. HILLS
Consulting Geologist
Midland, Texas
Box 418 Phone 1015

J. E. (BRICK) ELLIOTT
Petroleum Engineer
Houston Club Houston, Texas
Duration address: Major J. E. Elliott
Dallas Chemical Warfare Procurement Office
700 Mercantile Bank Bldg., 106 Ervay St.,
Dallas, Texas

F. B. Porter, *President* R. H. Fash, *Vice-President*
THE FORT WORTH LABORATORIES
Analyses of Brines, Gas, Minerals, Oil, Interpretation of Water Analyses. Field Gas Testing.
828½ Monroe Street FORT WORTH, TEXAS
Long Distance 138

W. G. SAVILLE J. P. SCHUMACHER A. C. PAGAN
GRAVITY METER EXPLORATION CO.
TORSION BALANCE EXPLORATION CO.
Gravity Surveys
Domestic and Foreign
1347-48 ESPERSON BLDG. HOUSTON, TEX.

CECIL HAGEN
Geologist
Gulf Bldg. HOUSTON, TEXAS

L. B. HERRING
Geologist
Natural Gas Petroleum
DRISCOLL BLDG. CORPUS CHRISTI, TEXAS

J. S. HUDNALL G. W. PIRTLE
HUDNALL & PIRTLE
Petroleum Geologists
Appraisals Reports
Peoples Nat'l. Bank Bldg. TYLER, TEXAS

JOHN S. IVY
Geologist
1124 Niels Esperson Bldg., HOUSTON, TEXAS

TEXAS

W. P. JENNY

Consulting Geologist and Geophysicist

Specializing in MICROMAGNETIC SURVEYS, GEOLOGICAL INTERPRETATIONS and CORRELATIONS of seismic, gravimetric, electric and magnetic surveys.

1404 Esperson Bldg. HOUSTON, TEXAS

MID-CONTINENT TORSION BALANCE SURVEYS
SEISMIC AND GRAVITY INTERPRETATIONS

KLAUS EXPLORATION COMPANY
H. KLAUS
Geologist and Geophysicist

115 South Jackson, Enid, Oklahoma
2223 15th Street, Lubbock, Texas

JOHN D. MARR

Geologist and Geophysicist

SEISMIC EXPLORATIONS, INC.

Gulf Building Houston, Texas

DABNEY E. PETTY

10 Tenth Street

SAN ANTONIO, TEXAS

No Commercial Work Undertaken

J. C. POLLARD
Robert H. Ray, Inc.
Rogers-Ray, Inc.

Geophysical Engineering

Gulf Building Houston, Texas

ROBERT H. RAY
ROBERT H. RAY, INC.

Geophysical Engineering

Gravity Surveys and Interpretations

Gulf Bldg. Houston, Texas

F. F. REYNOLDS

Geophysicist

SEISMIC EXPLORATIONS, INC.

Gulf Building Houston, Texas

E. E. ROSAIRE
SUBTERREX
BY
Geophysics and Geochemistry

Esperson Building Houston, Texas

WEST VIRGINIA

WM. H. SPICE, JR.

Consulting Geologist

2101-02 Alamo National Building
SAN ANTONIO, TEXAS

DAVID B. REGER

Consulting Geologist

217 High Street

MORGANTOWN WEST VIRGINIA

WYOMING

E. W. KRAMPERT

Geologist

P.O. Box 1106

CASPER, WYOMING

GEOLOGICAL AND GEOPHYSICAL SOCIETIES

COLORADO

ROCKY MOUNTAIN ASSOCIATION OF PETROLEUM GEOLOGISTS
DENVER, COLORADO

President - - - - - - - - - Ben H. Parker
Colorado School of Mines, and Frontier Refining Company
1st Vice-President - - - - - Dart Wantland
Colorado School of Mines
2nd Vice-President - - - - Wm. B. Kramer
U. S. Geological Survey
Secretary-Treasurer - - - - - A. W. Weeks
Petroleum Administration for War
320 First National Bank Building

Luncheons every Friday noon, Cosmopolitan Hotel. Evening dinner (6:15) and program (7:30) first Monday each month or by announcement, Cosmopolitan Hotel.

INDIANA-KENTUCKY

INDIANA-KENTUCKY GEOLOGICAL SOCIETY
EVANSVILLE, INDIANA

President - - - - - - - George R. Wesley
Skelly Oil Co.

Vice-President - - - - - - Robert F. Eberle
The Superior Oil Company

Secretary-Treasurer - - - - Hillard W. Bodkin
The Superior Oil Company

Meetings will be announced.

LOUISIANA

NEW ORLEANS GEOLOGICAL SOCIETY
NEW ORLEANS, LOUISIANA

President - - - - - - - - - H. C. Petersen
Freeport Sulphur Co., American Bank Bldg.
Vice-President and Program Chm. - - - - - - - - - - - - - - Dean F. Metts
Humble Oil and Refining Company
1405 Canal Bldg.
Secretary-Treasurer - - - - - B. E. Bremer
The Texas Company, P.O. Box 252

Meets the first Monday of every month, October-May inclusive, 7:30 P.M., St. Charles Hotel. Special meetings by announcement. Visiting geologists cordially invited.

LOUISIANA

SOUTH LOUISIANA GEOLOGICAL SOCIETY
LAKE CHARLES, LOUISIANA

President - - - - - - - - - H. E. McGlasson
Stanolind Oil and Gas Company
Vice-President - - - - - - - - - C. B. Roach
Shell Oil Company, Inc.
Secretary - - - - - - - - - - A. L. Morrow
Magnolia Petroleum Company
Treasurer - - - - - - - - - D. N. Rockwood
Union Producing Company

Meetings: Luncheon 1st Wednesday at Noon (12:00) and business meeting third Tuesday of each month at 7:00 P.M. at the Majestic Hotel. Visiting geologists are welcome.

ILLINOIS

ILLINOIS GEOLOGICAL SOCIETY

President - - - - - - - - Darsie A. Green
The Pure Oil Company, Box 311, Olney

Vice-President - - - - - - - Clark T. Snider
Lario Oil and Gas Company, Mt. Vernon

Secretary-Treasurer - - - - - Fred H. Moore
Magnolia Petroleum Corp., Box 535, Mt. Vernon

Meetings will be announced.

KANSAS

KANSAS GEOLOGICAL SOCIETY
WICHITA, KANSAS

President - - - - - - - - - - Leo R. Fortier
Alpine Oil and Royalty Co.
Vice-President - - - - - - - Virgil B. Cole
Gulf Oil Corporation
Secretary-Treasurer - - - - Delbert J. Costa
Superior Oil Co. of California
417 First Natl. Bank Bldg.
Manager of Well Log Bureau - Harvel E. White

Regular Meetings: 7:30 P.M., Geological Room, University of Wichita, first Tuesday of each month. Visitors cordially welcomed.

The Society sponsors the Kansas Well Log Bureau which is located at 412 Union National Bank Bldg.

LOUISIANA

THE SHREVEPORT GEOLOGICAL SOCIETY
SHREVEPORT, LOUISIANA

President - - - - - - - - - W. H. Spears
Union Producing Company, Drawer 1407
Vice-President - - - - - - - T. H. Philpott
Carter Oil Company, Drawer 1739
Secretary-Treasurer - - - - - - E. P. Ogier
c/o W. C. Spooner, Box 1195

Meets the first Tuesday of every month, September to May, inclusive, 7:30 P.M., Criminal Courts Room, Caddo Parish Court House. Special meetings and dinner meetings by announcement.

MICHIGAN

MICHIGAN GEOLOGICAL SOCIETY

President - - - - - - - - George D. Lindberg
Sun Oil Company, Toledo, Ohio
Vice-President - - - - Edward J. Baltrusaitis
Gulf Refining Company, Box 811, Saginaw
Secretary-Treasurer - - - - Mrs. Lucille Esch
State Geological Survey, Lansing
Business Manager - - - - - William Schulz
Cities Service Oil Co., Mt. Pleasant

Meetings: Bi-monthly from November to April at Lansing. Afternoon session at 3:00, informal dinner at 6:30 followed by discussions. (Dual meetings for the duration.) Visiting geologists are welcome.

MISSISSIPPI

MISSISSIPPI GEOLOGICAL SOCIETY
JACKSON, MISSISSIPPI

President - - - - - - - - - K. K. Spooner
The Atlantic Refining Company, Box 2407

Vice-President - - - - - Lyman C. Dennis
Pure Oil Company, Box 1141

Secretary-Treasurer - - - - - C. L. Morgan
Consulting, Edwards Hotel

Meetings: First and third Wednesdays of each month, from October to May, inclusive, at 7:30 P.M., Edwards Hotel, Jackson, Mississippi. Visiting geologists welcome to all meetings.

OKLAHOMA

ARDMORE GEOLOGICAL SOCIETY
ARDMORE, OKLAHOMA

President - - - - - - - - - C. C. Hannum
The Texas Company

Vice-President - - - - - - - - - J. P. Gill
Sinclair Prairie Oil Company

Secretary-Treasurer - - - - J. M. Westheimer
Samedan Oil Corporation, Box 959

Dinner meetings will be held at 7:00 P.M. on the first Wednesday of every month from October to May, inclusive, at the Ardmore Hotel.

OKLAHOMA

OKLAHOMA CITY GEOLOGICAL SOCIETY
OKLAHOMA CITY, OKLAHOMA

President - - - - - - - - - I. Curtis Hicks
Phillips Petroleum Company
1211 First National Building

Vice-President - - - - - - E. G. Dahlgren
Interstate Oil Compact Commission
State Capitol

Secretary-Treasurer - - - - Theodore G. Glass
Sinclair Prairie Oil Company
703 Colcord Building

Meetings: Technical program each month, subject to call by Program Committee, Oklahoma City University, 24th Street and Blackwelder. Luncheons: Every Thursday, at 12:00 noon, Skirvin Hotel Coffee Shop.

SHAWNEE GEOLOGICAL SOCIETY
SHAWNEE, OKLAHOMA

President - - - - - - - - Edwin A. Dawson
1829 N. Broadway

Vice-President - - - - - - - Roy McAninch
Stanolind Oil and Gas Company, Box 1099

Secretary-Treasurer - - - - Marcelle Mousley
Atlantic Refining Company

Meets the fourth Thursday of each month at 8:00 P.M., at the Aldridge Hotel. Visiting geologists welcome.

TULSA GEOLOGICAL SOCIETY
TULSA, OKLAHOMA

President - - - - - - - - Robert E. Garrett
Consulting Geologist, 301 Beacon Building

1st Vice-President - - - - - - - J. V. Howell
912 Philtower

2nd Vice-President - - - - - - - Jerry E. Upp
Amerada Petroleum Corporation

Secretary-Treasurer - - - - - James A. Price
W. C. McBride, Inc., 625 Wright Bldg.

Editor - - - - - - - - - - Roy L. Ginter
Ginter Laboratory

Meetings: First and third Mondays, each month, from October to May, inclusive, at 8:00 P.M., University of Tulsa, Kendall Hall Auditorium. Luncheons: Every Tuesday (October-May), Bradford Hotel.

TEXAS

CORPUS CHRISTI GEOLOGICAL SOCIETY
CORPUS CHRISTI, TEXAS

President - - - - - - - - - Frith C. Owens
Consulting, Nixon Building

Vice-President - - - - - - - - E. D. Pressler
Humble Oil and Refining Company, Box 1271

Secretary-Treasurer - - - John Bruce Scrafford
Consulting, Driscoll Building

Regular luncheons, every Wednesday, Petroleum Room, Plaza Hotel, 12:05 P.M. Special night meetings, by announcement.

DALLAS PETROLEUM GEOLOGISTS
DALLAS, TEXAS

President - - - - - - - - Joseph M. Wilson
Continental Building

Vice-President - - - - - - - Henry C. Cortes
Magnolia Petroleum Company

Secretary-Treasurer - - - - H. C. Vanderpool
Seaboard Oil Company

Executive Committee - - - - Cecil H. Green
Geophysical Service, Inc.

Meetings: Regular luncheons, first Monday of each month, 12:00 noon, Petroleum Club, Adolphus Hotel. Special night meetings by announcement.

TEXAS

EAST TEXAS GEOLOGICAL SOCIETY

TYLER, TEXAS

President - - - - - - - - - G. J. Loetterle
Shell Oil Company, Inc., Box 2037
Vice-President - - - - - - - - B. W. Allen
Gulf Oil Corporation
Secretary-Treasurer - - - - - - L. L. Harden
Sinclair Prairie Oil Company, Box 1100
Executive Committee - - - - J. H. McGuirt
Magnolia Petroleum Company

Meetings: Monthly and by call.
Luncheons: Every Monday at 12:00 noon, Blackstone Hotel.

FORT WORTH GEOLOGICAL SOCIETY

FORT WORTH, TEXAS

President - - - - - - - - Karl A. Mygdal
The Pure Oil Company, Box 2107
Vice-President - - - - - William J. Hilseweck
Gulf Oil Corporation
Secretary-Treasurer - - - Richard H. Schweers
The Texas Company, Box 1720

Meetings: Luncheon at noon, Texas Hotel, first and third Wednesdays of each month, jointly with Petroleum Engineers Club. Visiting geologists welcome.

HOUSTON GEOLOGICAL SOCIETY

HOUSTON, TEXAS

President - - - - - - - - - Leslie Bowling
Union Oil Company of California
Vice-President - - - - - - W. B. Milton, Jr.
Gulf Oil Corporation
Secretary - - - - - - - - - - W. B. Moore
Atlantic Refining Company, Box 1346
Treasurer - - - - - - - - - G. J. Smith
Pan American Producing Company

Regular meeting held the first and third Thursdays at noon (12 o'clock), Mezzanine floor, Texas State Hotel. For any particulars pertaining to the meetings write or call the secretary.

NORTH TEXAS GEOLOGICAL SOCIETY

WICHITA FALLS, TEXAS

President - - - - - - - Dan D. Heninger
The Ohio Oil Company, 615 Hamilton Bldg.
Vice-President - - - - - - - Dolph E. Simic
Cities Service Oil Co.
Secretary-Treasurer - - - Carlos M. Ferguson
Magnolia Petroleum Co., 500 Waggoner Bldg.

Luncheons and evening programs will be announced.

SOUTH TEXAS GEOLOGICAL SOCIETY

SAN ANTONIO, TEXAS

President - - - - - - Wm. H. Spice, Jr.
Consulting, 2101 Alamo National Building
Vice-President - - - - - Harvey Whitaker
Consulting, 1409 Milam Building
Secretary-Treasurer - - - - Arthur H. Petsch
The Ohio Oil Co., 1417 Milam Building

Meetings: Third Tuesday of each month in San Antonio. Luncheon every Monday noon at Milam Cafeteria, San Antonio.

WEST TEXAS GEOLOGICAL SOCIETY

MIDLAND, TEXAS

President - - - - - - - - Fred H. Wilcox
Magnolia Petroleum Company
Vice-President - - - - - Prentiss D. Moore
Moore Exploration Company
Secretary-Treasurer - - - - - Dana M. Secor
Atlantic Refining Company

Meetings will be announced

WEST VIRGINIA

THE APPALACHIAN GEOLOGICAL SOCIETY

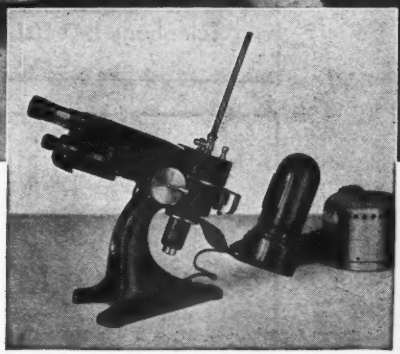
CHARLESTON, WEST VIRGINIA
P. O. Box 2385

President - - - - - - - Charles Brewer, Jr.
Godfrey L. Cabot, Inc., Box 1473
Vice-President - - - - - - - H. J. Wagner
Public Service Commission
Secretary-Treasurer - - - - Cramon Stanton
United Carbon Company, Box 1913
Editor - - - - - - - - - Robert C. Lafferty
In Service (Navy)

Meetings: Second Monday, each month, except June, July, and August, at 6:30 P.M., Kanawha Hotel.

THE SOCIETY OF EXPLORATION GEOPHYSICISTS

President - - - - - - - - - R. D. Wyckoff
Gulf Research and Development Company
Pittsburgh, Pennsylvania
Vice-President - - - - William M. Rust, Jr.
Humble Oil & Refining Company, Houston, Texas
Editor - - - - - - - - - - J. A. Sharpe
Stanolind Oil and Gas Company, Tulsa, Oklahoma
Secretary-Treasurer - - - - - - Hart Brown
Brown Geophysical Company, Box 6005
Houston, Texas
Past-President - - - - - - Frank Goldstone
Shell Oil Company, Inc., Houston, Texas
Business Manager - - - - - - - J. F. Gallie
P.O. Box 1923, Washington, D.C.



Bausch & Lomb Precision axid Refractometer

The "Optical Physical" For Fighting Fuels

Today, the American petroleum industry is providing the airmen of the United Nations with the most powerful fighting fuels in the world.

In the production of these, the Bausch & Lomb Precision Refractometer has had an important part. This instrument, developed to meet a definite peacetime need for high precision and dependability, is typical of the many Bausch & Lomb products now performing major roles in the war effort.

Today, the skills in design, computation and craftsmanship that make available such instruments as the Bausch & Lomb Precision Refractometer are also being applied to the instruments of war that make American gunnery so effective. Here again, when Victory is won, Bausch & Lomb will be able to extend its optical service to peace time pursuits because of its wartime accomplishments.

For Bausch & Lomb Instruments essential to Victory—priorities govern delivery schedules.

BAUSCH & LOMB

OPTICAL CO. • ROCHESTER, N. Y.

ESTABLISHED 1853

AN AMERICAN SCIENTIFIC INSTITUTION PRODUCING OPTICAL GLASS AND INSTRUMENTS FOR MILITARY USE, EDUCATION, RESEARCH, INDUSTRY AND EYESIGHT CORRECTION

FIRST IN OIL FINANCING

1895—1944

The FIRST NATIONAL BANK
and Trust Company of Tulsa

MEMBER FEDERAL DEPOSIT INSURANCE CORPORATION

THE GEOTECHNICAL CORPORATION

Roland F. Beers
President

1702 Tower Petroleum Building
Telephone L D 101 Dallas, Texas

REPORT OF A SYMPOSIUM ON PETROLEUM DISCOVERY METHODS

CONDUCTED BY THE RESEARCH COMMITTEE, A. I. LEVORSEN, CHAIRMAN, AT THE 27TH ANNUAL MEETING OF THE ASSOCIATION, AT DENVER, APRIL 21, 1942

164 PP. LITHOPRINTED. 8.5 x 11 INCHES. PAPER COVER

PRICE, $1.00, POSTPAID

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

Wartime Conditions and Western's Service

Western's unusually complete facilities for geophysical exploration are now being taxed to the limit to meet the wartime needs of operators requiring efficient, accurate and reliable surveys . . .

However—WESTERN will not compromise on the quality of its work by going beyond its capacity to achieve dependable results, either by reducing the amount of time, expense and effort required to provide the latest type instruments and equipment for each field party, or by placing the responsibility for surveys in the hands of partially trained or inexperienced crews.

Thus, while continuing a healthy expansion program that has always been a part of its established policy, WESTERN makes this pledge to its customers:

Any WESTERN survey made for you today will be made to the same high standards of accuracy and dependability as before the war . . . and while our services may not be as readily available due to current limitations, we will attempt to meet the demands of our clients to the best of our ability and capacity anywhere in the United States.

Western GEOPHYSICAL COMPANY

HENRY SALVATORI, PRESIDENT

EDISON BLDG., LOS ANGELES, CALIF. ★ PHILCADE BLDG., TULSA, OKLA. ★ ESPERSON BLDG., HOUSTON, TEXAS

PRACTICAL PETROLEUM ENGINEERS' HANDBOOK

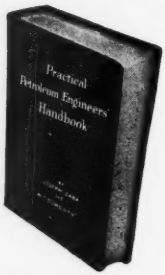
SECOND EDITION

Revised and Enlarged

By JOSEPH ZABA, E.M.M.Sc.

and

W. T. DOHERTY



This book was written by practical oil men. The tables were compiled so that they can be used by anyone to meet practical field situations without further calculations, and will fit 99% of the conditions under which the average operator is working in the field.

The second edition of the PRACTICAL PETROLEUM ENGINEERS' HANDBOOK has been completely revised and enlarged. The many changes which have been made during the past two years in the Standard Specifications of the American Petroleum Institute, particularly in pipe specifications, are incorporated in the new edition. Several tables are rearranged and charts enlarged to facilitate their use. Table of Contents and Index are more complete. Also about 90 pages of new formulae, tables, charts and useful information have been added.

This handbook was compiled and published for the purpose of saving the time of operators, engineers, superintendents, foremen and others.

TABLE OF CONTENTS

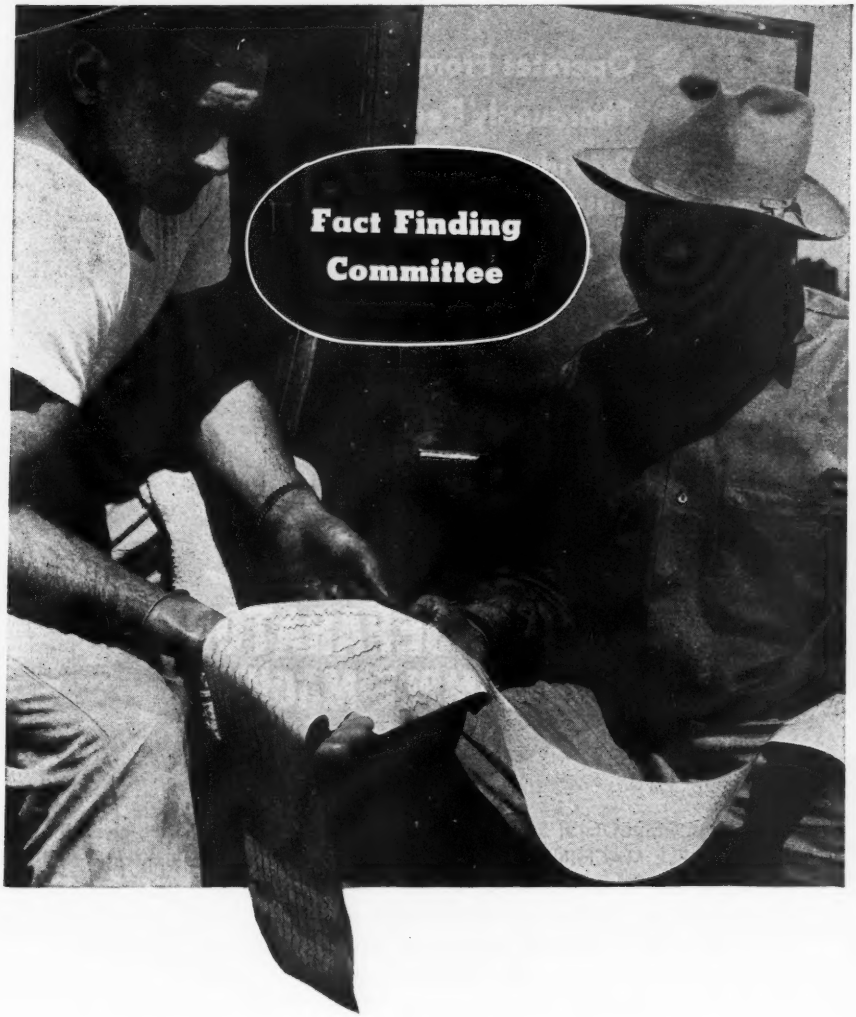
Chapter I —General Engineering Data
Chapter II —Steam
Chapter III —Power Transmission
Chapter IV —Tubular Goods
Chapter V —Drilling
Chapter VI —Production
Chapter VII —Transportation

Semi-Flexible Fabrikoid Binding, size 6 x 9, 492 Pages. Price: $5.00 Postpaid

Send Checks to the

GULF PUBLISHING COMPANY

P. O. BOX 2608, HOUSTON, TEXAS



General's seismologists have acquired a rich background of experience in geophysical exploration during nearly a decade of operations in the nation's most active oil provinces. This experience is being exploited fully today to help replenish our oil reserves that are being drawn on so heavily to attain victory.

General
GEOPHYSICAL COMPANY GGC HOUSTON

- Operates From Flow of Mud!!
- Thoroughly Reconditions Mud!
- Provides Accurate Sample of Cuttings!

THE *Thompson*
SHALE SEPARATOR
AND SAMPLE MACHINE

"THE GEOLOGIST'S BEST FRIEND" . . . that's the recognition given the SAMPLE MACHINE which is important and standard equipment on all Thompson Shale Separators. This SAMPLE MACHINE is one of the most successful methods now employed to secure true samples of both cuttings and sand from all formations drilled. Its operation is very simple and the results extremely accurate. The samples are obtained from a portion of the returns from the flow line which are diverted through a bypass into the SAMPLE MACHINE where all cuttings are thoroughly washed and deposited into a sample box. A sample of mud is then diverted into another sample box where it settles. The samples thus obtained are ready for ACCURATE analysis.

As Simple As Reading A Log!

Manufactured by
THOMPSON TOOL CO., INC.
Sold Through Supply Stores Everywhere
Phone 3521 Iowa Park, Texas

SEISMIC

SUBSURFACE SURVEYS

SEISMIC EXPLORATIONS, INCORPORATED • HOUSTON, TEXAS

TRIANGLE BLUE PRINT & SUPPLY COMPANY

Representing
W. & L. E. Gurley
Spencer Lens American Paulin

Complete Reproduction Plant
Instruments Repaired

12 West Fourth Street, Tulsa, Oklahoma

TECTONIC MAP OF SOUTHERN CALIFORNIA
BY R. D. REED AND J. S. HOLLISTER

In 10 colors. From "Structural Evolution of Southern California," *BULL. A.A.P.G.* (Dec., 1936). Scale, ⅛ inch = 1 mile. Map and 4 structure sections on strong ledger paper, 27 x 31 inches, rolled in tube, postpaid, $0.50.

The American Association of Petroleum Geologists, Box 979, Tulsa 1, Oklahoma

GULF COAST OIL FIELDS

Forty-Four Papers Reprinted from the *Bulletin* of The American Association of Petroleum Geologists with a Foreword by Donald C. Barton

EDITED BY **DONALD C. BARTON *AND* GEORGE SAWTELLE**

PRICE: $4.00, EXPRESS OR POSTAGE FREE
($3.00 to A.A.P.G. members and associate members)

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

THE JOURNAL OF GEOLOGY

a semi-quarterly
Edited by
ROLLIN T. CHAMBERLIN

Since 1893 a constant record of the advance of geological science. Articles deal with problems of systematic, theoretical, and fundamental geology. Each article is replete with diagrams, figures, and other illustrations necessary to a full scientific understanding.

$6.00 a year
$1.00 a single copy

Canadian postage, 25 cents
Foreign postage, 65 cents

THE UNIVERSITY OF CHICAGO PRESS

The Annotated
Bibliography of Economic Geology
Vol. XIV, Nos. 1 & 2

Orders are now being taken for the entire volume at $5.00 or for individual numbers at $3.00 each. Volumes I-XIII can still be obtained at $5.00 each.

The number of entries in Vol. XIV is 1,978.

Of these, 540 refer to *petroleum, gas,* etc., and *geophysics.* They cover the world, so far as information is available in war time.

If you wish future numbers sent you promptly, kindly give us a *continuing* order.

An Index of the 10 volumes was issued in May, 1939. Price: $5.00

Economic Geology Publishing Co.
Urbana, Illinois, U.S.A.

WANTED!

—Additional oil production to fuel ALLIED ARMIES

"The demands of war are tremendous." Both North and South American Oil Producers are constantly studying production estimates in order to recover every drop of available oil.

This vital job cannot be done simply by opening a valve. In many fields it will be necessary to institute a complete remedial program for old wells if production schedules are to be met.

PRODUCING MORE OIL WITH LESS STEEL

Lane-Wells Services and Products—*Radioactivity Well Logging, Gun Perforator, Packers, Liner Hangers and Drillable Bridging Plugs*—are designed and maintained to enable operators to produce more oil with less steel.

Radioactivity Well Logging accurately locates secondary producing zones in new or old wells through single or multiple strings of casing. These secondary zones are hidden reserves that can be opened by the *Lane-Wells Gun Perforator* and placed in production.

Lane-Wells Bridging Plugs and Packers make possible efficient plug-back and multiple zone production in wells where these practices are economical. Whatever your plans for remedial work, get in touch with your nearest Lane-Wells Field Branch. You'll find it pays to "Call Lane-Wells and have the job done right."

GUN PERFORATOR
RADIOACTIVITY WELL LOGGING
PACKERS
LINER HANGERS
DRILLABLE BRIDGING PLUGS

FIGHTING *Tomorrow's Tools-Today!*

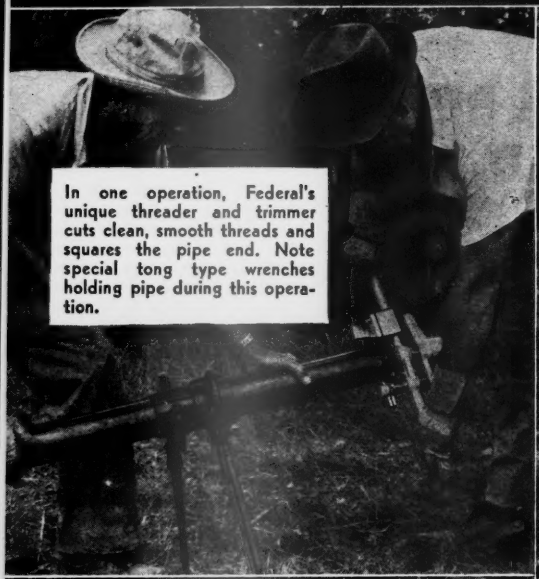
LANE-WELLS COMPANY

FACTORY, GENERAL AND EXPORT OFFICES
5610 SOUTH SOTO STREET, LOS ANGELES
Houston Oklahoma City
30 BRANCHES **24-HOUR SERVICE**

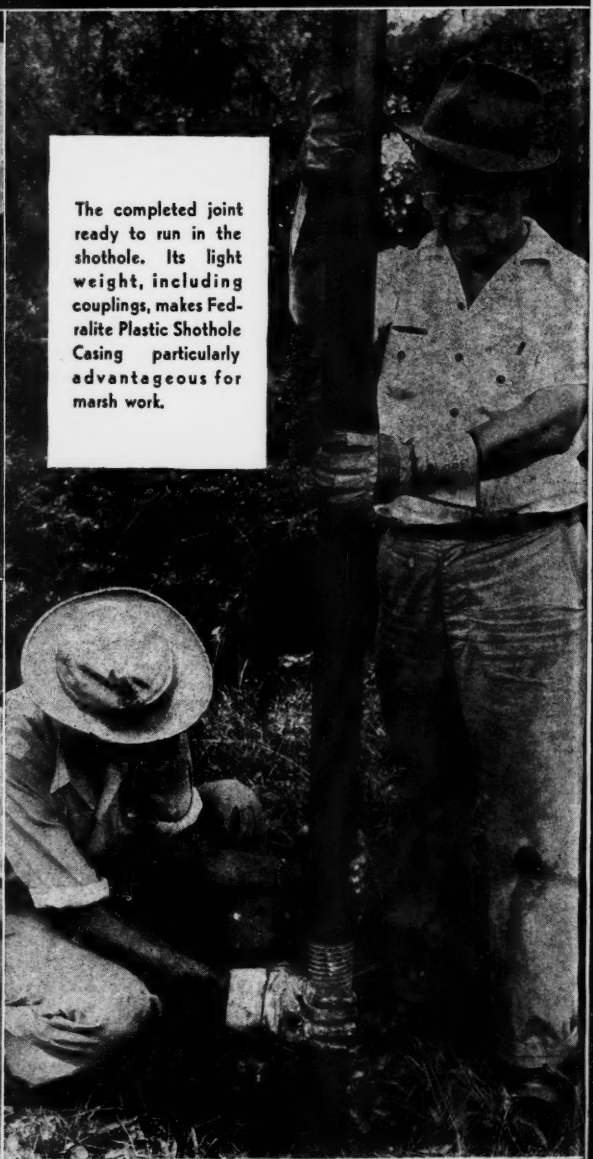
HOW TO MAKE STRONG, TIGHT JOINTS QUICKLY WITH

FEDRALITE PLASTIC SHOTHOLE CASING

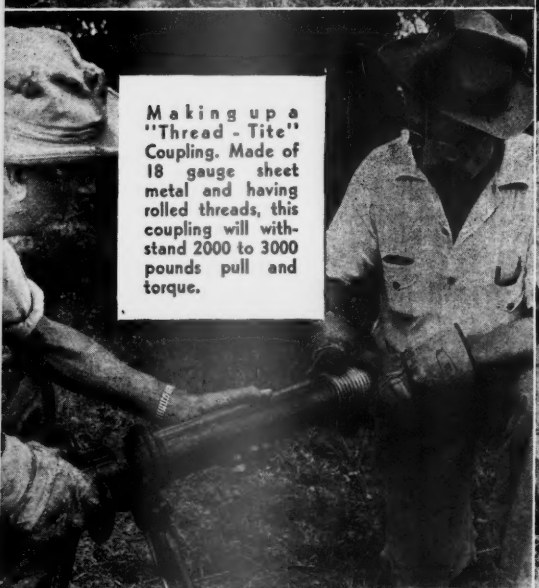
. . . IN THE FIELD!



In one operation, Federal's unique threader and trimmer cuts clean, smooth threads and squares the pipe end. Note special tong type wrenches holding pipe during this operation.



The completed joint ready to run in the shothole. Its light weight, including couplings, makes Fedralite Plastic Shothole Casing particularly advantageous for marsh work.



Making up a "Thread - Tite" Coupling. Made of 18 gauge sheet metal and having rolled threads, this coupling will withstand 2000 to 3000 pounds pull and torque.

FEDERAL ELECTRIC COMPANY, INC.

PLASTIC DIVISION

700 WAUGH DRIVE, HOUSTON • 8700 S. STATE ST., CHICAGO

CONTINUOUS GROWTH..

The Measure of Acceptance of

1 CREW IN 1935

4 CREWS IN 1937

10 CREWS IN 1939

13 CREWS IN 1941

24 CREWS IN 1944

National GEOPHYSICAL COMPANY
DALLAS • TEXAS

SEISMIC SURVEYS

STRATIGRAPHIC TYPE OIL FIELDS

THIRTY-SEVEN ORIGINAL ARTICLES BY FIFTY-TWO AUTHORS

Edited by A. I. LEVORSEN, *Tulsa, Oklahoma*

Assisted by N. WOOD BASS	*North Mid-Continent States*
ROSS L. HEATON	*Rocky Mountain States*
W. S. W. KEW	*California*
D. PERRY OLCOTT	*South Mid-Continent States*
THERON WASSON	*Eastern States*

Fields Described

CALIFORNIA—Edison and Kern Front fields
COLORADO—Greasewood field
KANSAS—Bush City, Chanute, Hugoton, Nikkel, Wherry, Zenith
KENTUCKY—Big Sinking field
LOUISIANA—University field
MICHIGAN—Shoestring gas fields
MONTANA-ALBERTA—Border-Red Coulee and Cut Bank
OHIO—Sand lenses
OKLAHOMA—Davenport, Dora, East Tuskegee, Olympic, Red Fork
PENNSYLVANIA—Music Mountain, Venango sands
TEXAS—Bryson, Cross Cut-Blake, Hardin, East Texas, Hitchcock, Hull-Silk, Lopez, Noodle Creek, O'Hern, Sand Belt, Seymour, Walnut Bend
WEST VIRGINIA—Gay-Spencer-Richardson, Shinnston
WYOMING—Osage field
ANNOTATED BIBLIOGRAPHY of 125 other fields

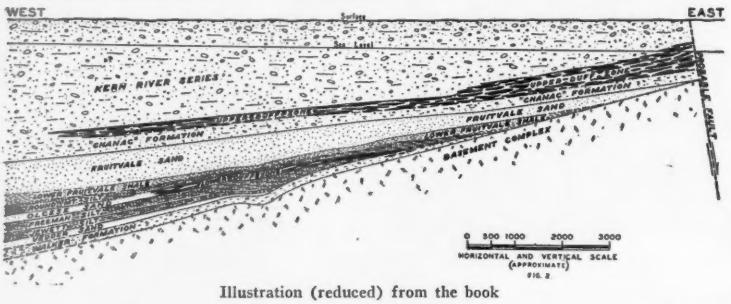


Illustration (reduced) from the book

The present volume . . . is intended as a factual background on which a further approach may be made to the causes of oil and gas accumulation and also as a basis for the reasoning necessary to future oil-field discovery.—From the editor's Foreword.

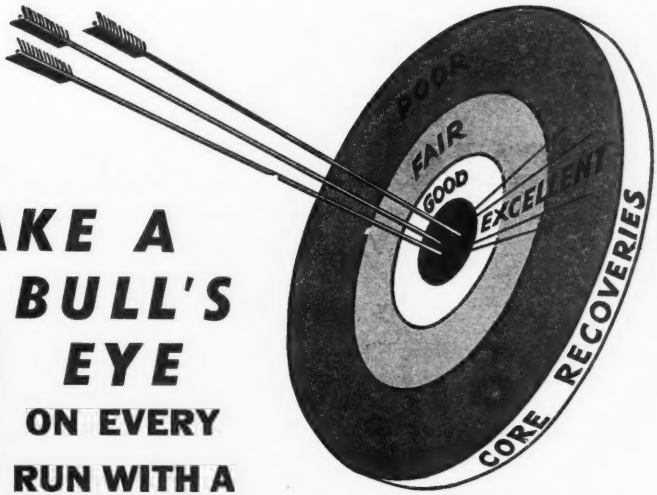
Journal of the Institute of Petroleum (London, May, 1942).—This new symposium forms an invaluable supplement to that in two volumes on *Structure of Typical American Oil-Fields*, published by the A.A.P.G. in 1929, in which the emphasis lay on the tectonic side. . . . The material presented and the manner in which it has been presented will be an education and inspiration for all students of petroleum production for many years to come.—Archie Lamont.

902 pp., 300 illus., 227 references in annotated bibliography

PRICE, $5.50, POSTPAID ($4.50 TO MEMBERS)

THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

CABLE TOOL OPERATORS



MAKE A BULL'S EYE ON EVERY RUN WITH A

BAKER *Cable Tool* CORE BARREL

BAKER Affords These Important Advantages:

- Higher percentage of recoveries in a wider range of formations
- Faster running time
- Lower maintenance cost
- Simplicity of operation
- Maximum safety in service
- Longer life
- Low initial cost

Complete details concerning this economical and efficient tool will be gladly furnished upon request—or see the new 1944 Composite Catalog.

BAKER OIL TOOLS, INC.

Box 127, Vernon Station, Los Angeles, Calif.
Central Division: Box 3048, Houston, Texas
Export Sales Office: 19 Rector Street, New York, N.Y.

Awarded to Los Angeles Plant 1943

BAKER CABLE TOOL CORE BARREL

1936

GEOLOGY
OF THE
TAMPICO REGION
MEXICO

By JOHN M. MUIR

CONDENSED TABLE OF CONTENTS

PART I. INTRODUCTORY. History. Topography. Drainage. (Pages 1-6.)
PART II. STRATIGRAPHY AND PALAEOGEOGRAPHY. Palaeozoic. Mesozoic. Tertiary. (7-142.)
PART III. IGNEOUS ROCKS AND SEEPAGES. Asphalt. Oil. Gas. (143-158.)
PART IV. GENERAL STRUCTURE AND STRUCTURE OF OIL FIELDS. Northern Fields and Southern Fields: Introduction, Factors Governing Porosity, Review of Predominant Features, Production, Description of Each Pool and Field, Natural Gas, Light-Oil Occurrences. (159-225.)
APPENDIX. Oil Temperatures. Salt-Water Temperatures. Well Pressures. Stripping Wells. Shooting and Acid Treating. Stratigraphical Data in Miscellaneous Areas. List of Wells at Tancoco. (226-236.)
BIBLIOGRAPHY (237-247). LIST OF REFERENCE MAPS (248). GAZETTEER (249-250).
INDEX (251-280).

"A volume that will mean the saving of countless hours of research to future workers in the Tampico region."—L. W. Stephenson, of the United States Geological Survey, in his introduction to the book.

"This book deals primarily with the geology of the Tampico embayment, but the author has viewed his objective with a broad perspective and presents the oil fields of that area against a background of the geologic history of Mexico. . . . [It] is an authoritative work by an expert on an area which has been one of the most important oil-producing regions of the world. The excellent areal geologic map of the Tampico embayment and the structure maps of the oil fields are significant contributions to Mexican geology. The extensive faunal lists from definite localities in each formation will be welcomed by students of earth history who seek to correlate the events in Mexico with the panorama of geologic development throughout the world."—Lewis B. Kellum, of the University of Michigan, in *Bull. Amer. Assoc. Petrol. Geol.*

"As a contribution to stratigraphy, this book is conspicuous for its discriminating and penetrating observations."—Helen Jeanne Plummer, of the University of Texas Bureau of Economic Geology, in *Jour. Paleon.*

- 280 pages, including bibliography and index
- 15 half-tones, 41 line drawings, including 5 maps in pocket
- 212 references in bibliography
- Bound in blue cloth; gold stamped; paper jacket. 6 x 9 inches

$4.50, post free
$3.50 to A.A.P.G. members and associates

The American Association of Petroleum Geologists
BOX 979, TULSA 1, OKLAHOMA, U.S.A.

Have YOU Taken This Step to EXTRA SAFETY

In these wartime days, when labor is often green, it is doubly important to take every step that leads to greater safety and reducing risks.

Atlas Manasite detonators provide an extra factor of safety—at no increase in cost. They have been made to withstand more friction, more impact—and they are reliable in action. They have been used in ever-increasing numbers since they were first introducd five years ago.

Take this extra step to safety—now. Your Atlas representative will be glad to tell you all about Atlas Manasite detonators.

MANASITE—Reg. U.S. Pat. Off.

ATLAS MANASITE DETONATORS

CHEMICALS ATLAS EXPLOSIVES

ATLAS
Powder Company
Wilmington 17, Delaware

An A.A.P.G. Book (1936) *An Invaluable Record*

GULF COAST OIL FIELDS

A SYMPOSIUM ON THE GULF COAST CENOZOIC

BY

FIFTY-TWO AUTHORS

FORTY-FOUR PAPERS REPRINTED FROM THE *BULLETIN* OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS WITH A FOREWORD BY DONALD C. BARTON

EDITED BY

DONALD C. BARTON

AND

GEORGE SAWTELLE

Kirby Petroleum Company

THE INFORMATION IN THIS BOOK IS A GUIDE FOR FUTURE DISCOVERY

"In the present volume the geologists of the Gulf Coast . . . are attempting to supplement that older volume [*Geology of Salt Dome Oil Fields*] with a partial record of the much new information of the intervening decade. . . . The quarter century preceding 1924 was the era of shallow domes. . . . Developments of the new era, however, came on with a rush. . . . The year 1925 saw the beginning of the extensive geophysical campaign which is still sweeping the Gulf Coast. . . . The deepest wells at the end of the decade are going below 10,000 feet instead of just below 5,000 feet. . . . Great increase in the depth of exploratory wells and of production is a safe prediction. . . . The area of good production should be extended southward into the Gulf Coast of Tamaulipas, Mexico. It may or may not be extended eastward into southern Mississippi. More good production should be established in the belt of the outcrop of the Pliocene, Miocene, and Oligocene. Many new, good oil fields should be discovered in the Lissie Beaumont area. . . . The coming decade, therefore, will probably be fully as prosperous for the Gulf Coast as the decade which has just passed."—From Foreword by Donald C. Barton.

- 1,084 pages, 292 line drawings, 19 half-tone plates
- Bound in blue cloth; gold stamped; paper jacket; 6x9 inches

PRICE: $4.00, POSTAGE FREE
($3.00 to A.A.P.G. members and associate members)

ORDER FORM

The American Association of Petroleum Geologists, Box 979, Tulsa 1, Oklahoma, U.S.A.

Enclosed is $....., for which please send to the undersigned: ..... copy (copies) of the clothbound book *Gulf Coast Oil Fields.*

Name .....

Address .....

GULF COAST OIL FIELDS

(See preceding page)

CONTENTS

		Page
Foreword	*Donald C. Barton*	ix
Aerial Photo-Mosaic of Barbers Hill Area, Texas	*Barton*	xvii

I. GENERAL AND THEORETICAL PAPERS

Oil-Producing Horizons of Gulf Coast in Texas and Louisiana	*Deussen*	1
Mechanics of Formation of Salt Domes with Special Reference to Gulf Coast Salt Domes of Texas and Louisiana	*Barton*	20
Fluid Mechanics of Salt Domes	*Nettleton*	79
Salt-Dome Statistics	*Sawtelle*	109
Texas and Louisiana Salt Dome Cap-Rock Minerals	*Hanna* and *Wolf*	119
Siderite in Cap Rock at Carlos Dome, Grimes County, Texas	*Rolshausen*	133
Hockley Salt Shaft, Harris County, Texas	*Teas*	136
Overhanging Salt on Domes of Texas and Louisiana	*Judson* and *Stamey*	141
Relation of Geophysics to Salt-Dome Structures	*Eby* and *Clark*	170
Gulf Coast Geosyncline	*Barton, Ritz,* and *Hickey*	192
Diastrophism in Topography of Corpus Christi Area, South Texas	*Price*	205
Surface Fracture System of South Texas	*Barton*	251
Corpus Christi Structural Basin Postulated from Salinity Data	*Price*	270
Variation and Migration of Crude Oil at Spindletop, Texas	*Barton*	309

II. STRATIGRAPHY

Vicksburg Group at Vicksburg, Mississippi	*Mornhinweg* and *Garrett*	335
Notes on the Vicksburg Group	*Cooke*	358
Subsurface Data on Covington County, Mississippi	*George* and *Bay*	369
Review of Tertiary Stratigraphy of Louisiana	*Howe*	383
Foraminiferal Zonation of Subsurface Claiborne of Texas and Louisiana	*Israelsky*	425
Post-Fleming Surface Formations of Southeast Texas and South Louisiana	*Doering*	432
Jackson Group of Formations in Texas with Notes on Frio and Vicksburg	*Ellisor*	470
Detailed Study of Some Beds, Commonly Known as Catahoula Formation, in Fayette Cunty, Texas	*Bowling* and *Wendler*	528
Reynosa Problem of South Texas, and Origin of Caliche	*Price*	550
Areal Geology of Eocene in Northeastern Mexico	*Kane* and *Gierhart*	588

III. DESCRIPTIONS OF OIL FIELDS AND SALT DOMES

SOUTH TEXAS

Driscoll Pool, Duval County, Texas	*Sheldon*	620
Government Wells Oil Field, Duval County, Texas	*Trenchard* and *Whisenant*	631
Greta Oil Field, Refugio County, Texas	*Stamey, Montgomery,* and *Easton*	648
McFaddin-O'Conner, Greta, Fox, Refugio, White Point, and Saxet	*Getzendaner*	664

SOUTHEAST TEXAS

Raccoon Bend Oil Field, Austin County, Texas	*Teas* and *Miller*	676
Sugarland Oil Field, Fort Bend County, Texas	*McCarter* and *O'Bannon*	709
Buckeye Field, Matagorda County, Texas	*Brucks*	734
Clay Creek Salt Dome, Washington County, Texas	*Ferguson* and *Minton*	757
Brenham Salt Dome, Washington and Austin Counties, Texas	*Burford*	780
Conroe Oil Field, Montgomery County, Texas	*Michaux* and *Buck*	789
Hoskins Mound Salt Dome, Brazoria County, Texas	*Marx*	833
Esperson Dome, Liberty County, Texas	*Goldston* and *Stevens*	857
Orange, Texas, Oil Field	*Deussen* and *Andrau*	880
Geology and Geophysics Showing Cap Rock and Salt Overhang of High Island Dome, Galveston County, Texas	*Halbouty*	909

SOUTHERN LOUISIANA

Geology and Geophysics of Southeast Flank of Jennings Dome, Acadia Parish, Louisiana, with Special Reference to Overhang	*Halbouty*	961
Jefferson Island Salt Dome, Iberia Parish, Louisiana	*O'Donnell*	983
Late Recent History of Côte Blanche Salt Dome, Saint Mary Parish	*Barton*	1026
Belle Isle Salt Dome, St. Mary Parish, Louisiana	*Barton*	1033
Discovery of Valentine (La Rose) Dome, Louisiana, by Reflection Seismograph	*Buchanan*	1040

EAST TEXAS

Mount Sylvan Dome, Smith County, Texas	*Wendlandt* and *Knebel*	1041

A PIONEER SERVICE DEDICATED TO THE ADVANCEMENT OF THE OIL INDUSTRY

Eighteen years ago, National Lead Company introduced BAROID to the oil industry. AQUAGEL was next developed, and then followed many other Baroid Products which have made valuable contributions to safer, faster, more economical drilling.

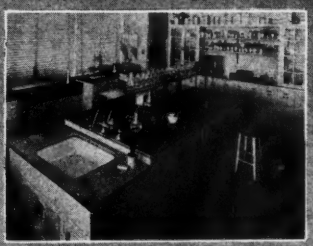
Unequalled laboratory service at Houston, Los Angeles, and Tulsa supplements the use of Baroid Products. Baroid technicians, in addition to maintaining and improving the quality of Baroid Sales Division's well-established products, are constantly at work developing new materials, new applications and new processes for the prevention of drilling troubles through mud control.

Baroid Service Engineers, in laboratory-equipped cars, cover the oil fields and provide a day-and-night service. This service, in collaboration with oil company mud engineers, has resulted in large savings for the oil industry by reducing drilling difficulties; by saving casing; and, in many cases, by the actual saving of wells.

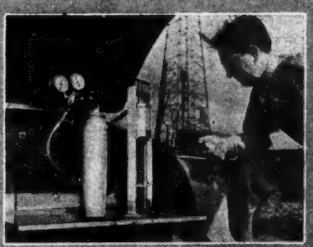
BAROID, and other Baroid Products, are immediately available in more than 400 locations in the United States and Canada.

BAROID SALES DIVISION
NATIONAL LEAD COMPANY
Baroid Sales Offices: Los Angeles 12 • Tulsa 3 • Houston 2

In this small laboratory at the Los Angeles plant, Baroid Sales Division pioneered in preventing drilling troubles.



Baroid Sales Division maintains modern laboratories at Los Angeles, Tulsa and Houston.

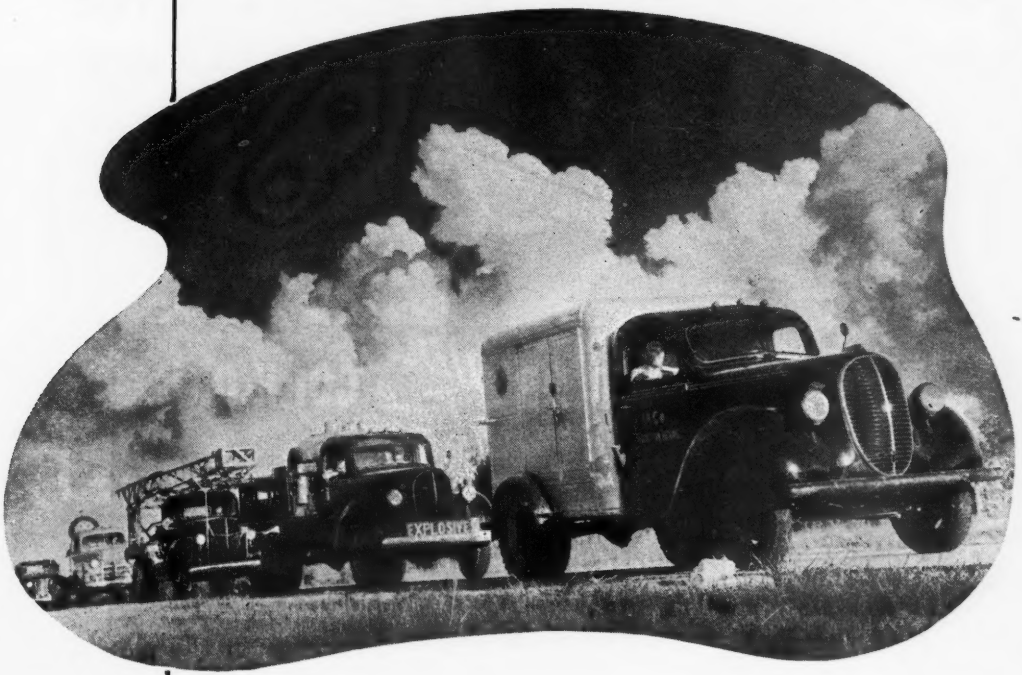


Baroid Service Engineer testing mud at well with Baroid Wall-building Tester.

Patent Licenses, unrestricted as to sources of supply of materials, but on royalty bases, will be granted to responsible oil companies and operators to practice the invention of any and/or all of United States Patents Nos. 1,807,082; 1,991,637; 2,041,086; 2,044,758; 2,064,936; 2,094,316; 2,119,829; 2,214,366; 2,294,877; 2,304,256 and further improvements thereof. Applications for Licenses should be made to Los Angeles office.

Baroid Products: Baroid and Colox • Aquagel • Fibrotex • Baroco • Stabilite • Aquagel-Cement • Smentrox
Impermex • Zeogel • Micatex • Anhydrox • Testing Equipment • Baroid Well Logging Service

This Crew knows how to Do the Job!

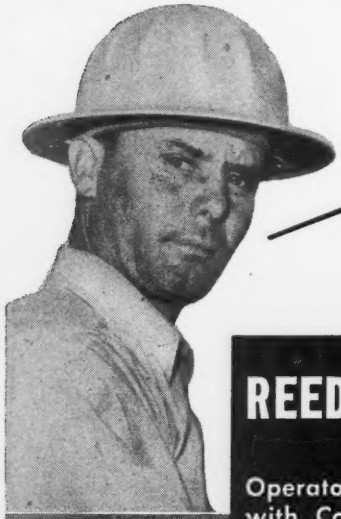


Whether you require a seismograph survey, a gravity meter survey or a magnetometer survey, the value of your report depends largely on the equipment, experience and skill of the crew in the field *and their interest in your job.*

Independent's record of many years service to the world's leading oil producers . . . surveys in twenty-four states and in foreign fields . . . merits your consideration.

POINTING THE WAY IXC FOR THE DRILL

Independent
EXPLORATION COMPANY
Houston, Texas



WE DEPEND ON THE REED FOR ALL OUR CORING JOBS!

REED 'BR' *Wire Line* CORE DRILL

Operators in every part of the world "Core with Confidence" with the Reed "BR" Wire Line Coring-Drilling Bit on bottom. They have learned through practice and experience that for positive results in hard or soft formations they can depend on Reed Core Drills.

COMPLETE CORING SERVICE
The REED KOR-KING CONVENTIONAL
The REED "BR" WIRE LINE
The REED STREAMLINED KOR-KING FOR SMALL HOLE DRILLING

HARD AND SOFT FORMATION HEADS INTERCHANGEABLE

REED ROTARY DRILLING TOOLS
SPEED-ECONOMY-DURABILITY

REED ROLLER BIT COMPANY

POST OFFICE BOX 2119 HOUSTON, TEXAS

G S I
Call in
G.S.I.
Whatever your exploration problems may be, the world-wide experience of G.S.I. is available to help you solve them. We invite you to consult us on your present and post-war programs. Call in G.S.I.
GEOPHYSICAL SERVICE INC.
EUGENE McDERMOTT, President
SEISMOGRAPH SURVEYS
BRANCH OFFICE: HOUSTON, TEXAS
DALLAS, TEXAS

WAR-TIME PRODUCTION with a peace-time background

Hughes Tool Company designed and built the Hughes Aircraft Strut Division . . . acted in a consulting capacity in the design and construction of the Dickson Gun Plant . . . furnished the entire executive and operating personnel for both plants . . . which are now in operation . . .

Founded upon the rotary method of drilling, Hughes Tool Company has for 34 years fought the peacetime battle for production of better drilling tools.

The experience and skill acquired over these years is now employed in the manufacture of such war products as gun barrels; airplane landing gear and propeller ferrules; armor plate, brake drums, and transmission parts for tanks; castings for synthetic rubber plants; struts, pump parts, rudder arms, rudder bearings, stuffing tubes, and other parts for ships—*these in addition to essential tools for the Oil Well Drilling Industry.*

HUGHES TOOL COMPANY

HOUSTON TEXAS

Senior Organization in Men and Management for

HUGHES AIRCRAFT STRUT DIVISION—DICKSON GUN PLANT—HUGHES AIRCRAFT COMPANY